National Aeronautics and Space Administration

Marshall Space Flight Center

Fiscal Year 1998 Annual Report

Statement of the Director

The 1998 Annual Report for the Marshall Space Flight Center covers the activities from October 1, 1997, through September 30, 1998, and includes the Center Financial Statements. FY98 proved to be another excellent year for the Center. As evidenced in the roles of Center of Excellence for Space Propulsion and key mission roles in Space Transportation Systems Development, Microgravity Research, and Space Optics Manufacturing Technology, Marshall plays a pivotal role in the future of the Agency.

Space transportation systems made great strides in meeting the technological challenges required to enable the next generation of reusable launch vehicles (RLV's). The year marked the beginning of hardware delivery for the X–33. Another technology demonstrator, the X–34 with the Marshall-developed Fastrac engine, also met key programmatic milestones. These efforts provide significant technology information to aid U.S. industry in building a full-scale RLV to meet the goal of substantially lowering the cost of space access. The Shuttle program propulsion elements continued to perform safely with increased reliability and reduced costs. We witnessed the first flight of the Super Lightweight Tank and the Shuttle Main Engine Block IIA configuration.

The Microgravity Research program continued broad, productive Earth-based and space-based research. A new treatment for influenza, developed with the aid of information from space-grown crystals, continues to advance through the drug development and approval process. Improvements in plant growth Light Emitting Diodes (LED's) by Quantum Devices have helped advance photodynamic cancer therapy, and improved and extended the lives of children with brain cancer.

Over the past year our optical manufacturing technology team has designed, developed, and tested numerous optical systems and technologies to help us better view and understand our universe. The Chandra optical system was tested at the Marshall Center in a new test facility. The launch of Chandra in the summer of 1999 promises untold discoveries.

Along with Unity, the U.S. Laboratory and the Airlock module were built by the Boeing Company in Marshall facilities in support of the *International Space Station* (*ISS*) effort. Additional Marshall responsibilities include the development and delivery of *ISS* integration hardware, the EXPRESS Rack, and integration and operation of *ISS* science experiments. Knowledge gained on the *ISS* will provide the fundamental building blocks for space commerce, and Marshall employees will help make it happen.

FY98 proved again the outstanding dedication and commitment of the Marshall employees. The accomplishments illustrate the scope of research and technology activities at the Center. It is through that dedication and effort that we will accomplish our mission of "bringing people to space—bringing space to people."

Arthur G. Stephenson
MSFC Center Director

Commitment to Safety and Mission Success

Our goal: Establish MSFC as number one in safety within NASA.

Marshall's safety philosophy: Senior management commitment to flight crew, employees, facilities, and program hardware safety.

NASA is committed to mission first—safety always. MSFC's safety goal is to be number one in safety within the Agency. In 1998 MSFC continued its unique and innovative management techniques to improve safety performance. Current safety processes include the collocation of key Safety and Mission Assurance personnel in the major project offices and at contractor plants; maintaining safety of flight while transitioning from oversight to insight and reducing Government Mandatory Inspection Points on Shuttle projects; senior management safety reviews of all MSFC payloads; Internet web pages with payload assurance information; the Center employee Safety Concern Reporting System; the use of state-of-art system safety tools for hazard identification and control; risk assessments to prioritize management decisions on corrective actions; and MSFC Safety Day Stand-Downs.

Some of the Safety Day activities included vendor safety booths.

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Marshall Space Flight Center FY 1998 Annual Report

Introduction

The Marshall Space Flight Center (MSFC), a field center of the National Aeronautics and Space Administration (NASA), was established on July 1, 1960, with the transfer of land, buildings, property, space projects, and personnel from the United States Army.

The Marshall-developed Mercury-Redstone vehicle boosted America's first astronaut on a suborbital flight in 1961. Marshall's first major program was the development of the Saturn rockets, the largest of which sent man to the Moon in 1969 and Skylab into orbit in 1973. Other successful projects in Marshall's history include the Lunar Roving Vehicle (1971), the three High Energy Astronomy Observatories (1977, 1978, and 1979), the Hubble Space Telescope (1990), and the Marshall-developed propulsion systems which launched America's first Space Shuttle.

Marshall remains one of NASA's largest field centers, occupying over 1,800 acres in Huntsville, Alabama, and employing over 2,800 civil servants. This number includes employees in resident offices at prime contractor's facilities and at the Michoud Assembly Facility in Louisiana. In 1998, Marshall's budget allocation was $2.33 billion, resulting in a direct impact of $722 million on the Alabama economy.

During the past fiscal year, approximately 25,106 contractor personnel were engaged in work for the Center. An additional 1,606 contractors were associated with *International Space Station* work being done by the Boeing company in Huntsville, and other Agency contracts.

Marshall's vision is to be the world's leader in space transportation systems, microgravity research, and space optics manufacturing technology, and to be a vital resource for the development and utilization of key scientific missions that will advance the frontiers of knowledge and human exploration. The employees of MSFC remain committed to this vision which is evidenced by their accomplishments over the past year, and their dedication to mission success in the future.

Facilities

Area	1,841 Acres
Buildings	162
Structures	68
Square Feet	4.1M
Replacement Cost	$1.1B
One-of-a-Kind Facilities	75

MSFC Employment (FY98)

Civil Servants	2,822
• 1,609 With B.A./B.S. Degrees	
• 468 With M.S. Degress	
• 147 With Ph.D. Dregrees	
Contractors	25,106

Contracts (FY98)

MSFC manages 934 active contracts, valued at $16.6 billion, awarded to contractors in 50 states and the District of Columbia.

MSFC Workforce by State*

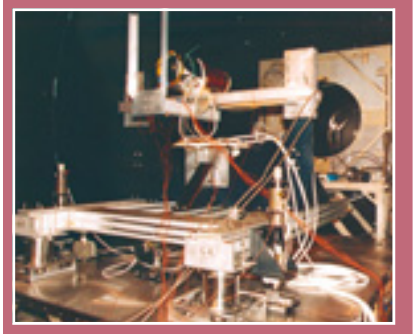
Alabama	9,152
California	6,205
Louisiana	2,899
Utah	2,776
Florida	1,445
Massachusetts	648
Illinois	454
Tennessee	375
Texas	339
Virginia	331
Colorado	326
Connecticut	302
Foreign	255
Mississippi	233
New Jersey	201
Minnesota	198
Maryland	180
New York	157
Ohio	147
Arizona	132
Wisconsin	111
Kansas	110
Other States	951
Total	**27,928**

* Civil servants, contractors, subcontractors, and vendors

Strategic Implementation

Marshall's mission—bringing people to space, bringing space to people.

The Space Shuttle docked with *Mir.*



Solar X-Ray Imager testing in the X-Ray Calibration Facility.

The NASA Strategic Plan defines the Agency's vision and mission and provides a basis for the Agency to manage its affairs effectively and efficiently. It enables critical decisions to be made regarding resource allocation and implementation activities, and establishes a process that ensures decisions are consistent with the goals, objectives, and strategies outlined in NASA's Strategic Plan and Performance Plan.

NASA has established four Strategic Enterprises as a business framework for making management decisions necessary to implement NASA's mission. They include the Human Exploration and Development of Space (HEDS) Enterprise, the Aero-Space (AS) Enterprise, the Space Science (SS) Enterprise, and the Earth Science (ES) Enterprise. Each Enterprise has a unique set of goals, objectives, and strategies that define how programs will be developed and delivered to external and internal customers.

Since the first MSFC Implementation Plan was issued in November 1996, Marshall employees have continually strived to achieve the goals and objectives defined in NASA's Strategic Plan. The Implementation Plan is the means by which strategies are established which enable Centers to carry out the requirements of the Enterprises through the programs and projects assigned. Included are assigned support activities and crosscutting functions necessary to assure the success of NASA's mission.

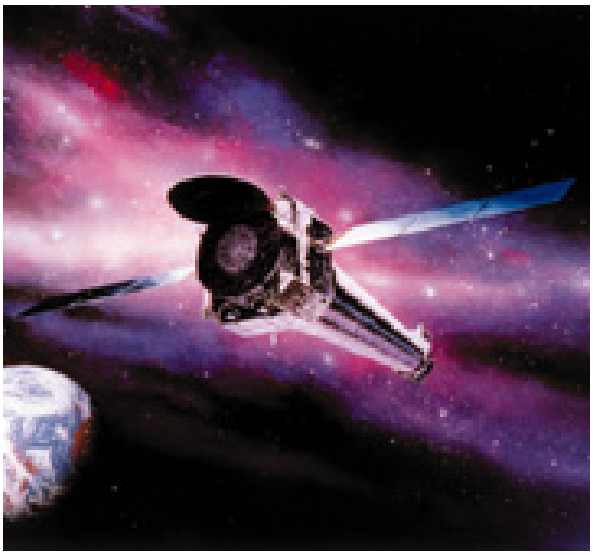
The Human Exploration and Development of Space Enterprise is dedicated to providing safe and affordable access to space, using the space environment to expand scientific knowledge, enabling the commercial development of space, sharing knowledge and technologies which enhance the quality of life on Earth, and preparing for human missions of exploration to the far reaches of the solar system. Marshall supports this Enterprise through its mission area assignment for Space Transportation Systems Development, Microgravity Research, and as the Center of Excellence for Space Propulsion. MSFC engineers are working to lower the cost of access to space by studying methods to lower operations, development, and manufacturing costs while increasing performance and enabling aircraft-like operability. Through Marshall's responsibility for implementing the Agency's microgravity initiatives, scientific and commercial researchers are able to generate new knowledge, products, and services that improve the quality of life on Earth. In support of the HEDS goal of safe and affordable access to space, Marshall is charged with developing and managing upgrades to the Space Shuttle Propulsion Systems which improve safety margins and increase lift capacity. Marshall is leading the development of advanced Earth-to-orbit and in-space propulsion systems and technologies required to expand the human presence in space.

The mission of the Aero-Space Enterprise is to enable the commercial expansion and exploration of space, provide world-class research and development services to support industry and government, and revolutionize air travel and aircraft manufacturing which in turn enables continued U.S. leadership in global civil aviation. As NASA's Lead Center for Space Transportation Systems Development and as the Center of Excellence for Space Propulsion, Marshall has implemented the Advanced Space Transportation Program (ASTP) and the RLV Technology Program. The ASTP and RLV programs are complementary space transportation technology development efforts. The

RLV program addresses near-term technology required for a next-generation reusable launch vehicle while the ASTP generates advanced space transportation technologies for future needs which are not addressed by the RLV program and required to meet the ambitious goals of cost reduction. Under the RLV program, Marshall is managing the development and testing of the X–33 and X–34 flight demonstrators.

The Space Science Enterprise aspires to probe deeper into the mysteries of the Universe, develop revolutionary technologies to support space science programs enabling future human exploration beyond low-Earth orbit, and contribute to the education goals of our Nation by sharing the excitement and inspiration of our missions and discoveries. Marshall's work in selected areas of astrophysics and space physics include high-resolution x-ray imaging and polarimetry, high-sensitivity gamma-ray astronomy, high-energy cosmic rays, solar magnetic fields, and low-energy space plasma physics. Marshall's mission area assignment in space optics manufacturing technology is vital in fostering research and development to advance the state of the art in optical manufacturing and testing. MSFC's responsibilities for managing scientific payloads and research include the Chandra X-Ray Observatory (CXO)—formerly known as the Advanced X-Ray Astrophysics Facility (AXAF), the Gravity Probe-B, the Solar X-Ray Imager, and the Solar B. Chandra, NASA's next major orbiting observatory, assures as many new astronomical discoveries regarding the violent x-ray universe as the Hubble Space Telescope provided in visible ultraviolet and infrared light.

The mission of the Earth Science Enterprise is to expand scientific knowledge of Earth systems using NASA's unique capabilities. Sharing this knowledge with the public and private sectors will enable the technology to be used to better understand the total Earth system and the effects of natural and human-induced changes on the global environment. Marshall supports this Enterprise primarily through the Global Hydrology and Climate Center (GHCC), a joint venture with the State of Alabama Space Science and Technology Alliance and the Universities Space Research Association. The GHCC focuses on using advanced technology to observe and understand the global climate system and apply this knowledge to areas such as agriculture, urban planning, water resource management, and operational meteorology. Ground, air, satellite, and Space Shuttle-based experiments have provided invaluable knowledge concerning the global water cycle, the physics of lightning, global temperature data, and the impact of human activity as it relates to global and regional climate.



Artist's concept of the CXO in orbit. The CXO, NASA's most powerful x-ray telescope, was fully assembled in FY98 with the integration of the spacecraft, the telescope, and the integrated science module (ISM).

Strategic implementation at NASA is necessary to ensure that limited resources are used wisely in the mission for which we are responsible. Marshall Space Flight Center can be proud of the tradition we have forged in the Nation's space program. Further, we can be excited about the role we will play in the future through support of all NASA Strategic Enterprises and maintaining NASA's reputation as the world leader in access to space. The Marshall team is well prepared for this challenge and looks forward to meeting the mission —bringing people to space, bringing space to people.

GHCC scientists used remote sensing to study ancient Mayan ruins.

Science and Technology Highlights

Reusable Launch Vehicle—X–33

Reusable Launch Vehicle—X–34

Advanced Space Transportation and Technology

As NASA's Center of Excellence for Space Propulsion and as the Lead Center for Space Transportation Systems, Marshall is responsible for various efforts committed to research, develop, verify, and transfer space and related technologies. This work mainly supports the Aero-Space Technology Enterprise. These activities are supported by partnerships with other NASA centers, the Department of Defense, and other government agencies. In addition, the Human Exploration and Development of Space Enterprise Mission is supported via the accomplishment of goals aimed at providing safe and affordable human access to space and enabling the commercial development of space. Significant progress in developing the technology required to enable the next generation launch vehicle and future transportation systems was achieved in fiscal year 1998.

X–33

Marshall's Space Transportation Programs Office manages the X–33 Advanced Technology Demonstrator, which is being built in partnership with Lockheed Martin Skunk Works. As part of NASA's RLV Program, the X–33 is the largest X plane, demonstrating technologies for single stage to orbit. The demonstrator is a 273,000-pound, wedge-shaped prototype launch vehicle which will launch vertically like a rocket, fly up to 260,000 feet at speeds approaching Mach 15, and land like an airplane. Fiscal year 1998 saw accomplishment of critical design review allowing the fabrication and assembly of the X–33 technology demonstrator to proceed. The official groundbreaking for the launch site at Haystack Butte on Edwards Air Force Base was held in November of 1997. Vehicle assembly then began with the delivery of the upper and lower and thrust structure caps and the composite thrust structure web. The placement of the liquid oxygen tank in the vehicle assembly tooling, and successful flight testing of Thermal Protection System material in July of 1998 signaled major milestones for the flagship of NASA's technology demonstrators. Before completion, the program will test and integrate new technologies including aerospike propulsion, lifting body aerodynamics, the world's largest composite liquid hydrogen tanks, and aircraft-like ground operations which enable a 2-day turnaround instead of months. Testing of the subscale prototype will provide the data necessary for industry to build a full-scale RLV that is expected to dramatically increase reliability and meet the goal of lowering the cost of putting a pound of payload into low-Earth orbit from $10,000 to $1,000.

X–34/Fastrac Engine

The X–34, launched from beneath an L–1011 airplane, will reach an altitude of 250,000 feet at speeds approaching Mach 8 before it touches down on a runway. This small demonstrator will help reduce the risk associated with developing a full-scale operational RLV early in the next decade and enable technologies to reduce the cost of future space transportation systems. Several major

milestones accomplished in fiscal year 1998 included critical design review on the main propulsion system, arrival of the turbopump for the X–34 Fastrac engine at Marshall, and completion of qualification tests on the first wing assembly before delivery to Orbital Sciences Corporation. Key technologies needed to develop a reusable launch vehicle will be demonstrated through ground development and flight test on the X–34. These include the low cost Fastrac engine, a graphite composite airframe, advanced thermal protection on leading edges, and automated flight operations using GPS. In January of 1998 NASA modified the X–34 contract with Orbital Sciences Corporation to produce a second flight vehicle for the program, which will bridge the gap between the earlier Clipper-Graham (DC–XA) and the larger and higher performance X–33.

Advanced Space Transportation Program

The Advanced Space Transportation Program is a focused technology program tailored to meet the future needs of the NASA Enterprises and the commercial space industry. The ASTP will pursue the development of revolutionary advancements in space access with the goal to realize a 10-fold reduction in the cost of space transportation in the next 10 years, and another 10-fold reduction within 25 years. The program will provide the propulsion and airframe system knowledge required to support flight demonstration projects while focusing on future breakthrough technologies beyond the next generation.

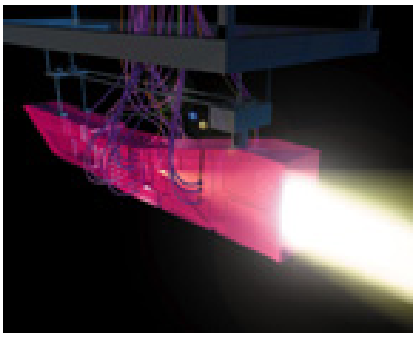
The ASTP includes five major thrusts: Small Payload Focused Technologies, Reusable Launch Vehicle Focused Technologies, Core Technologies, In-Space Technologies, and Space Transportation Research/Interstellar Transportation. A brief discussion of each project follows.

750K injector test for the Marshall-developed Fastrac engine in the Center's East Test Area.

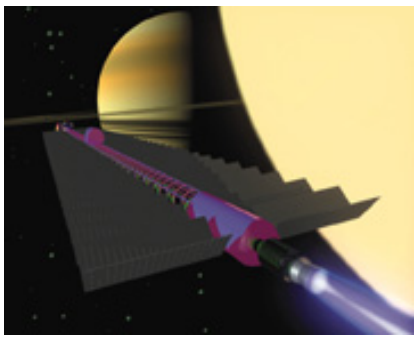
- **Small Payload Focused Technologies—**Small Payload Focused (Bantam) activities are developing advanced reusable technologies applicable to systems capable of launching small science and technology payloads. The highlight of FY98 was the delivery of the Fastrac engine to the Stennis Space Center for testing in support of the X–34. In addition, several low-cost component technologies were successfully demonstrated. A low-cost turbopump was designed, fabricated and assembled that has reduced the Fastrac engine turbopump cost by a factor of 3. Bench verification testing of a rocket engine controller based on a Chrysler automotive computer was completed. A modular propulsion avionics suite was delivered and is ready for bench testing. A PC-based launch control and mission planning system was demonstrated in bench tests. Engine injector testing was initiated and compatibility tests are being conducted for hydrogen peroxide composite tanks.

- **Reusable Launch Vehicle Focused Technologies—**RLV Focused activities are developing airframe systems and propulsion technologies to reduce the cost of access to space to $1,000/lb in 10 years. Tasks are complementary to, but do not duplicate, the work funded by X–33. In FY98, technology development has been initiated for durable thermal protection systems, lightweight conformal structures, increased component life capability, low-cost manufacturing, lightweight airframe and propulsion components and advanced power systems.

- **Core Technologies—**The emphasis of the Core Technologies area is development and demonstration of reusable airframe and propulsion technologies that will reduce the cost of access to space to $100/lb in 25 years. Crucial technology advancement is required to increase performance margins which in turn lead to longer life and reduced maintenance costs in future reusable space transportation systems. The focus of core activities in FY98 was advanced propulsion, specifically, the development of rocket-based combined cycle (RBCC) technologies. In 1998, 2 integrated RBCC flowpaths, one by Aerojet and one by Boeing-Rocketdyne, were built and tested. The testing was conducted from sea-level static (Mach 0) to Mach 8. The test program included both direct-connect and free-jet tests. Several "first-time" tests were conducted. The first was a dynamic test that varied both the



RBCC test engine.



The use of fusion for propulsion has the potential to open the entire solar system for exploration.

air enthalpy and the Mach number as the flowpath transitioned from the air-augmented rocket (AAR) to ramjet operating mode. The second was the performance of a Mach 8 scramjet at high dynamic pressures of 1,000 lbs/ft^2. Combustion wave ignition was utilized to ignite the multiple rockets integrated within the flowpath. Integrated flowpath testing is being conducted at General Applied Sciences Laboratory (GASL) located in Ronkonkoma, NY. Results to date indicate that the flowpaths are performing as anticipated. Future testing will continue on both flowpaths to improve performance and operability issues.

- **In-Space Technologies—**The In-Space Technologies project is studying technologies intended to increase performance over today's chemical space transfer systems. Technologies being pursued include tethers for transportation systems, solar thermal propulsion and solar electric propulsion systems. Deep Space 1, launched in November 1998 and powered by NASA Solar Electric Propulsion Technology Application Readiness (NSTAR), marked the first time that nonchemical propulsion was used as the primary means of propelling a spacecraft. This project has helped demonstrate the solar electric engine's suitability for long term missions.

- **Space Transportation Research—**The Space Transportation Research project provides the basic research function of the ASTP program. The activity focuses on advanced concepts for enabling breakthroughs in space transportation and maturing these revolutionary ideas via small, critical technology experiments and breadboard validations. Research areas include advanced concepts for launch augmentation, pulse detonation engines, high-energy propellants, and high-energy concepts and materials which hold promise for enabling exciting new missions that are beyond the realm of present technological capability. In FY98 the antimatter-triggered fusion research continued to show progress towards the eventual objective of trapping, cooling and transporting antiprotons from Fermi Labs to the Air Force Shiva-Star Facility for micro fusion experiments. Two pulse detonation engine test articles have been constructed and have begun initial tests to demonstrate the engineering feasibility of rocket engines based on this promising technology. Short track tests of a magnetic levitation breadboard were conducted to investigate its potential application for launch assist. Free-flight tests of a laser-powered launch vehicle were conducted using a ground-based laser on a small test article.

- **Other Accomplishments—**Marshall's Space Transportation Programs Office supported other efforts focused on enabling a next generation reusable launch vehicle. The Space Transportation Architecture Study was initiated in September with five industry teams and an internal NASA team. The Marshall team also accepted the transfer of the X–38 Deorbit Propulsion Stage Project from Johnson Space Center. At Marshall, FY98 saw substantial progress in development of the technology required for future reusable launch vehicles and space transportation systems to support NASA's long term goals.

Advanced Concepts and Studies

Marshall is pursuing a number of initiatives committed to long-range technological advancement. In FY98, a number of concepts and studies were undertaken in addition to providing support to the Advanced Space Transportation and Technology initiative. Highlights of some of the more intriguing concepts are detailed below.

NASA's Advanced Space Transportation Program at MSFC is developing cutting edge technologies to dramatically reduce the cost of space transportation.

Development of Space

In 1998, the MSFC Program Development Directorate began new initiatives focused on "…enabling the development of space for human enterprise" as stated in the NASA Agency Mission. Precursor work was initiated in 1997, with NASA/MSFC studies on the feasibility of space business parks and public space travel. In 1998 these studies continued, and included a "new space industries" workshop and funding for determining the feasibility of space solar power for terrestrial use. In the spring, a Development of Space Planning Team was appointed by the Center Director to further define the concept and explore Marshall's role in space development. The team concluded that the Center's expertise in both transportation and microgravity could significantly contribute to the implementation of the Development of Space initiative. This effort is continuing to grow and will provide insight into the transportation and microgravity technology development activities required for future commercial enterprises in space.

Virtual Research Center

In 1998, the Virtual Research Center (VRC) supported over 1,500 users on more than 90 project teams. The VRC provides a suite of web accessible tools that facilitate work among geographically distributed team members. These tools include a document management system, a topic discussion forum, a calendar, an action item tracker, an electronic mail list, and a team directory. Project information is password protected and a firewall was added in 1998 to provide additional security. Plans for 1999 include incorporating encryption, an object-oriented architecture, and a hierarchical data management structure. Members of the VRC team are actively supporting the Intelligent Synthesis Environment (ISE) initiative.

Space Solar Power

In 1998, the Marshall Center led an inter-Center and external team in the Space Solar Power (SSP) Concept Definition Study, which identified commercially viable SSP concepts along with technical and programmatic risks. Products from this study included innovative concepts for generating electricity in geosynchronous-Earth orbit and transmitting power to the ground via microwaves to support science, exploration and commercial applications. Associated with these concepts were technology roadmaps focused on commercially viable concepts that could be implemented in the 2020 to 2030 time frame. In 1999, MSFC will lead the NASA SSP Exploratory Research and Technology effort to conduct preliminary strategic technology research and development to enable large, multi-megawatt SSP systems and wireless power transmission for government missions and commercial markets (in-space and terrestrial).

Space Solar Power: A power generation system in space for transfer to Earth or to other space platforms.

Space Shuttle

The Space Shuttle, America's first reusable launch vehicle, still remains the workhorse of the space program. With the launch of the first *International Space Station* components, and in supporting the remaining assembly schedule, the Shuttle will continue in this role into the next millennium. Space Shuttle propulsion was originally developed by Marshall and continues to improve through an infusion of new technology in all the propulsion elements.

The Space Shuttle being mated with the ET and the Solid Rocket Boosters (SRB's).

Space Shuttle

In fiscal year 1998, Marshall's Space Shuttle Projects Office supported four safe and successful Space Shuttle launches including the conclusion of the U.S. and Russian *Mir* Space Station missions. Paramount in the operation of the Shuttle is safety. Today we continue to fly safely with over 60 successful launches since return to flight. Another major thrust in the operation of the Shuttle is lowering the costs associated with flight. Daily operations are transitioning to United Space Alliance (USA), a commercial company responsible for lowering costs associated with flying the Shuttle in order to free up resources for other NASA projects including a series of new reusable launch vehicles. In 1998 the Solid Rocket Booster Project successfully consolidated the prime contract with United Space Boosters, Incorporated, into USA's Space Flight Operations Contract. This is the first of four Marshall-managed Shuttle contracts planned for USA consolidation. Marshall's Shuttle workforce continues to downsize experiencing a cumulative 50 percent reduction in civil servants along with a 40 percent reduction in contractor personnel since 1992. This has resulted in a 40 percent cost savings for the Marshall related elements. In this environment, Shuttle projects office personnel were still able to pursue key enhancements which increased reliability and reduced costs. A few of these enhancements are detailed below.

External Tank

The External Tank (ET) Project reached an important milestone when the first Super Lightweight Tank (SLWT) achieved flight with the launch of STS–91. This was a significant step in successful

The super lightweight external fuel tank.

deployment of the *International Space Station* because the new tank is the same size as the old one but over 7,000 pounds lighter. For each pound removed from the external tank, a pound of payload can be added. In the external tank this performance gain is critical to *ISS* payload requirements. The tank, which weighs 1.7 million pounds at liftoff, is taller than a 15-story building and has a diameter of 27 feet, making it the largest single component of the Shuttle. It holds the liquid hydrogen and liquid oxygen propellants in two separate tanks for the Shuttle's three main engines. The SLWT is manufactured by Lockheed Martin at NASA's Michoud Assembly Facility.

Space Shuttle Main Engine

The redesigned Space Shuttle main engine (SSME), referred to as the Block IIA configuration, achieved first flight with the new large throat main combustion chamber on STS–89. The new design reduces peak pressure and temperature, and has more than doubled the reliability of the engine. The SSME, originally developed by Marshall in the 1970's, still remains the world's most sophisticated reusable rocket engine. In a little over 8 minutes the three main engines provide liftoff thrust, throttling, control, and insertion. The fuel turbopump, which weighs about the same as one automobile engine, produces as much horsepower as 28 diesel locomotives. Each engine is 14 feet long, weighs about 7,000 pounds, and is 7.5 feet in diameter at the end of its nozzle.

Solid Rocket Motor

The solid rocket motors, which only burn for 2 minutes, produce about 80 percent of the thrust for each Shuttle launch. These motors represent the largest operational solid rocket motors in the world and generate 5.3 million pounds of thrust at liftoff. In fiscal year 1998, the Reusable Solid Rocket Motor Project conducted a successful full-scale static test firing which incorporated 67 test objectives. These tests are essential to provide verification of critical design and manufacturing processes in light of the inherent inability to accept test flight motors.

SSME during a test fire.

International Space Station

The *International Space Station (ISS)* is a cooperative effort involving much of the world community. Once operational, it will allow a continuous human presence in space for many years to come. Marshall plays a major role in the development and operation of the *ISS*, from manufacturing and testing hardware to *ISS* research and science operations.

The *International Space Station* depicted with the Space Shuttle docked.

Sixteen nations are involved in the development of the *ISS*. They include the United States, Russia, Japan, Canada, Belgium, Denmark, Brazil, France, Germany, Italy, The Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom. The *ISS* will weigh about 950,000 pounds when completed and support a crew of up to seven. It will include five pressurized laboratories and attached external sites for research. Construction of the *ISS* is scheduled for completion in the year 2003.

MSFC's *ISS* responsibilities include: development of the regenerative life support systems for crew and research animals; management oversight of two node elements, the Multipurpose Logistics Module and the Interim Control Module; development of research facilities including the EXPRESS Rack; integration of Spacelab pallets and support equipment for *ISS* assembly; environmental qualification testing of major *ISS* elements and systems; and management of the payload operations and utilization activities for research activities onboard the *ISS*. Marshall performs all preflight dynamic and structural testing of U.S. *ISS* elements in addition to providing qualification testing of some *ISS* components.

The first component of the *ISS*, known as Node1 or "Unity," was manufactured by the Boeing Company at MSFC. The node is made of aluminum and has six hatches which serve as docking ports for other *ISS* modules. Along with Unity, the U.S. Laboratory and the airlock module were also built by Boeing in facilities provided by Marshall. Unity was shipped to the Kennedy Space Center and accepted in September for flight on STS–88.

Nodes 2 and 3 are being developed by the Italian Space Agency (ASI), with Marshall providing project management and technical oversight. In fiscal year 1998 Node 2 completed

Preliminary Design Review and Node 3 completed requirements review. In this past year Marshall also developed a water recycling and oxygen generation system and established contracts for development of these technologies. This will eliminate the need to resupply thousands of pounds of water and oxygen to the *ISS* crew each year.

Marshall also provides the facilities for structural and environmental testing of the Common Berthing Mechanism (CBM), the mechanism that physically joins two *ISS* elements together and creates an airtight interface between them. Unity CBM Latch and Meteoroid Debris Mechanisms Acceptance and Qualification Tests were successfully completed in the past year along with the Truss Structural Strength/Static Test and the Airlock Modal Test.

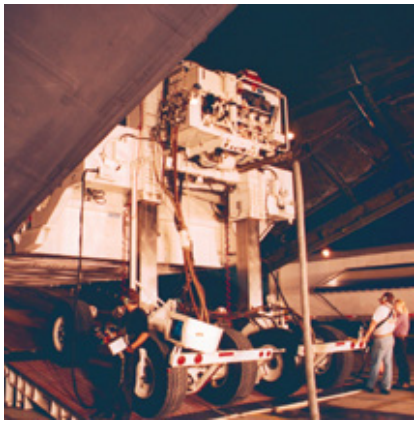
Marshall responsibilities in the *ISS* payloads arena encompass both specific development tasks and broader integration tasks. The development tasks include the design, development, and testing of the Microgravity Science Glovebox, which will allow astronauts to safely conduct experiments in an enclosed laboratory with the use of gloves. Combustion, fluid physics, biotechnology, and materials science experiments can be undertaken in an environment that would otherwise be considered hazardous without the use of the Glovebox.

The MSFC broader integration task is that of payload operations. NASA has the role of leading the International Partners in the integration of Space Station operations, and the MSFC operations team in the Payload Operations Integration Center (POIC) at the Huntsville Operations Support Center (HOSC) has been delegated cognizance over payload operations. At the international level, the team performs the planning and real-time control functions of the POIC. For U.S. payloads, there is a more detailed role of integration to conduct specific operation of NASA's onboard science assets. To implement these capabilities, the mission operations development team is providing new ground system capabilities within the historic HOSC facility and the POIC, which provide innovative data systems solutions that take advantage of new technologies for data processing and connectivity.

An important feature is the teleoperations concept which distributes monitoring and the control of science payloads to the experimenter in a remote center. To that end, the development team has produced the Telescience resource Kit (TreK) solution which bundles command and telemetry functions with voice and video connectivity into a PC-based platform. This innovation will begin a new era of commercial avenues for low-cost telescience operations for NASA's *ISS* science customers.

Looking to the future, the *ISS* will provide the fundamental building blocks for space commerce such as space solar power and commercial space parks.

Node 2 Aft Cylinder at the *ISS* production facility in MSFC building 4708.



Unity is loaded into the back of a C–5 Galaxy aircraft for shipment to Kennedy Space Center to undergo prelaunch tests.

Microgravity Research Program

As the Lead Center for NASA's Microgravity Research Program, MSFC manages microgravity research projects at Marshall and other NASA Centers. In accordance with NASA's Strategic Plan, the Microgravity Research Program seeks to use the microgravity environment of space as a laboratory to advance knowledge, to explore the nature of physical phenomena contributing to progress in science and technology on Earth, and to study the role of gravity in technological processes, building a scientific foundation for understanding the consequences of gravitational environments beyond Earth's boundaries.

Onboard STS–73, USML–2: Mission Specialist, Payload Commander, Kathryn Thornton with Crystal Growth Furnace (CGF).

The Significance of Microgravity

Gravity is such an accepted part of our lives that we rarely think about it, even though it affects everything we do. Any time we drop or throw something and watch it fall to the ground, we see gravity in action. Although gravity is a universal force, there are times when it is not desirable to conduct scientific research under its full influence. In these cases, scientists perform their experiments in microgravity, a condition in which the effects of gravity are greatly reduced. This is sometimes described as "weightlessness."

A microgravity environment provides a unique laboratory in which scientists can investigate the three fundamental states of matter: solid, liquid, and gas. Microgravity conditions allow scientists to observe and explore phenomena and processes that are normally masked by the effects of Earth's gravity.

The challenge facing NASA's microgravity research program is to use space flight time wisely and to conduct the most scientifically promising research possible. The Microgravity Research Program (MRP) is responsible for managing a comprehensive research program which is currently made up of five major science research areas. These include biotechnology, combustion science, fluid physics, fundamental physics, and materials science. The MRP supports and coordinates researchers with a wide range of backgrounds, forming an interdisciplinary microgravity science community that conducts research and disseminates the results of the program. The MRP also assists the science community's research through the development of suitable

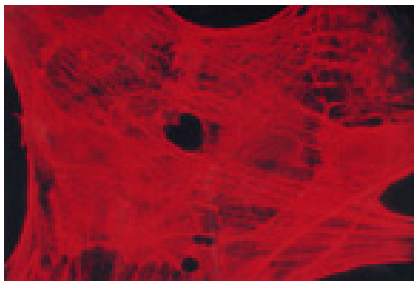
experiment instruments for selected projects and the selection of the most suitable vehicle for each experiment.

Microgravity Research Areas

Marshall is assigned authority and responsibility to manage and execute the science diciplines of biotechnology and materials science. Glenn Research Center is assigned lead in areas of combustion science and fluid physics, and the Jet Propulsion Laboratory is responsible for fundamental physics.

- **Biotechnology—**The NASA MRP's Biotechnology discipline focuses on the development of new technologies to enhance current biological research and to open up new avenues of related research. As one of the most dynamic segments of our high technology economy, biotechnology is playing an increasingly important role in medical research and the development of pharmaceutical drugs, agricultural research and products, and environmental protection. NASA's microgravity biotechnology program contributes to three major areas of research which include fundamental biotechnology science, protein crystal growth, and cell and tissue culturing.

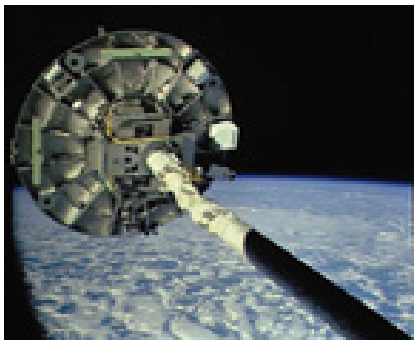
- **Combustion Science—** Combustion has been a subject of vigorous scientific research for over a century. Studies of combustion are motivated by important public health and economic problems. Combustion processes directly cost in excess of $200 billion each year in the United States. Air pollution, produced in large part by combustion-generated particulates, contributes to approximately 60,000 U.S. deaths each year. Unwanted fires cause approximately 5,000 deaths, 26,000 injuries and costs $26 billion in property losses yearly. The effects of global warming and changes in the ozone layer pose public health and economic problems that are potentially enormous. We now know that space offers unprecedented opportunities for critical measurements needed to understand and resolve practical combustion problems.



Biomedical research offers hope for a variety of medical problems.

- **Fluid Physics—**Fluid physics is the study of the motion of fluids and the effects of such motion. Since three of the four states of matter (gas, liquid and plasma) are fluid and even the fourth (solid) behaves like a fluid under many conditions, fluid physics is vital to understanding, controlling, and improving all of our industrial as well as natural processes. The engines used to propel a car or an airplane, the shape of the wings of an airplane that allow it to fly, the operation of boilers that generate steam used to produce over 90 percent of the world's electric power, and understanding how pollutants are transported and dispersed in air and water are just a few examples of how fluid physics affects our everyday life.

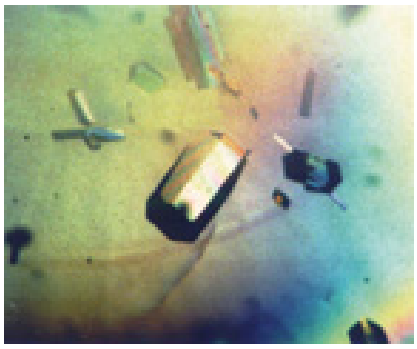
  A low-gravity environment nearly eliminates buoyancy and sedimentation and provides scientists near ideal conditions to probe into flow phenomena otherwise too complex to study on Earth. It also allows the study of flows (such as surface tension driven flows) that are nearly completely masked in Earth's gravity.



The Wake Shield Facility (WSF) is a free-flying research and development facility that is designed to use the pure vacuum of space to conduct scientific research in the development of new materials. The thin film materials technology developed by the WSF could some day lead to applications such as faster electronics components for computers.

- **Fundamental Physics—**The fundamental physics research program sponsors research which explores the physics governing matter, space, and time. It seeks to discover and understand the organizing principles of nature, including the emergence of complex structures. Pursuit of this research will expand our understanding of the world and the universe and lay the foundation for scientific breakthroughs of the future.

  The fundamental physics research program currently supports research in three areas. These include gravitational and relativistic physics, laser cooling and atomic physics, and low-temperature and condensed-matter physics. A fourth research area, high-energy physics, is being considered for support in the future.



A lysozyme crystal grown on STS–81. It serves as a protein model for documentation of the effects of microgravity on crystal growth.

- **Materials Science—** Microgravity materials scientists seek to use microgravity to study the processes by which materials are produced and the relationships between the formation of a material and its properties. To this end, the program attempts to advance the fundamental understanding of the physics and chemistry associated with phase changes—when a material changes from one phase (liquid, solid, or gas) to another. The materials science program supports both fundamental research and applications-oriented investigations of electronic and photonic materials, glasses and ceramics, metals and alloys, and polymers.

  A fundamental objective of microgravity materials science research is to gain a better understanding of how buoyancy driven convection and sedimentation affect the processing of materials. In microgravity, these gravity driven phenomena are suppressed, allowing researchers to study the phenomena that are obscured by the effects of gravity and difficult or impossible to study quantitatively on Earth. For example, in microgravity, the significant reduction of buoyancy driven convection makes it possible for scientists to study segregation, a phenomenon that influences the distribution of a material's components as it forms from a liquid or gas.

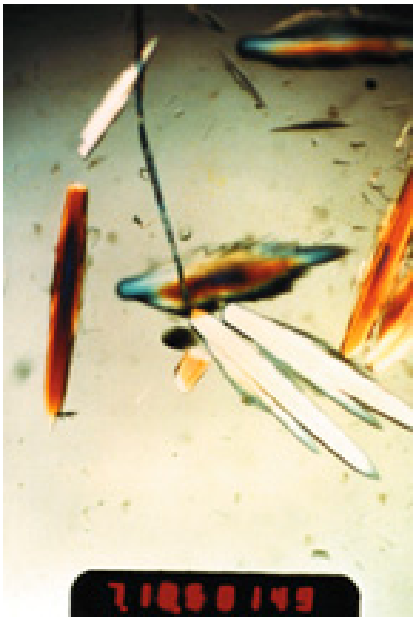
Microgravity Research Highlights

Significant research activities occurred in fiscal year 1998, primarily in two Space Shuttle missions that saw the completion of two major activities. The following is a sample of these activities.

During FY 1998, the MRP conducted broad, productive Earth-based and space-based research. The fourth United States Microgravity Payload (USMP–4) mission was successfully completed in the final flight of this successful series. Two studies focused on the process of crystal growth of advanced, "solid-solution" semiconductor materials that serve as infrared detectors. The growth speed and crystal size of a material that serves as a model for industrially useful metals was measured for the first time, without the effects of gravity. Joint American-French research provided the first evidence of certain important crystal growth driving forces in engineering materials whose properties depend strongly on crystallographic direction. Research using NASA's bioreactor was also carried out on the Neurolab mission (STS–90) providing the first information on how microgravity affects the functions of genes. An experiment carried out on STS–89 provided a basic understanding of the phenomena that contribute to earthquakes and grain silo explosions.

Microgravity researchers measured the viscosity of the gas xenon to within 0.6 micro-Kelvin of its critical temperature, 30 times closer than has been achieved on Earth. This allows testing of fundamental physical principles of viscosity and fluid behavior and allows extrapolation to a larger phenomena such as the weather, underground oil extractions, fluid transportation in a pipe, cryogenic fluids, and superconductors.

MRP's activities in the NASA/*Mir* Science Program were completed. Research operations in protein crystal growth using the Gaseous Nitrogen Dewar demonstrated the ability of the new technique to screen a large number of crystal growth conditions at a lower cost than prior Shuttle missions. Crystals grown on *Mir* of Human Immunodeficiency Virus (HIV) protease inhibitors had better resolution and quality than those grown on Earth, and may assist ground-based researchers in defining the structure of the protein which may prove important in fighting the Auto



(PCG) Protein Crystal Growth Horse Serum Albumin grown aboard STS–50, USML–1. The most abundant blood serum protein regulates blood pressure and transports ions, metabolites, and therapeutic drugs.

Biotechnology research in Protein Crystal Growth is leading to the development of new vaccines for fighting diseases.

Immune Deficiency Syndrome (AIDS) virus. Perhaps even more significant is the large number of trials conducted growing "model" proteins. These efforts are helping to uncover nature's laws that govern crystal growth both on Earth and in space. Analysis of this data will require 2 years and may lead to improved crystal growth techniques on Earth as well as successful growth on the *ISS* of important proteins related to major diseases.

NASA and National Institutes of Health (NIH) cooperative activities to transfer the results of microgravity research to the biomedical community is a major focus. Researchers at the NASA/NIH Center for Three-Dimensional Tissue Culture have already produced the first in vitro tissue system which permits the study of HIV pathogeneses inside human lymphoid tissue. In addition, there are currently 15 ongoing projects at the center addressing a spectrum of biomedical research issues that the NIH identified as having the potential to benefit from the NASA tissue culture technology. To further accelerate NASA bioreactor research on the culturing of human tissues, NASA has renewed this important initiative with the NIH for 4 additional years.

Microgravity crystal growth provided the ultra-high resolution of protein structure, Respiratory Syncytical Virus (RSV). RSV infects nearly 4 million children ages 1 to 5 each year. Approximately 100,000 of them require hospitalization and 4,000 die annually. The virus is considered by physicians to be the most serious infectious disease affecting infants in the United States. The principle investigator (PI) is working with a drug manufacturer to allow them to make the drug more effective.

Microgravity Space Product Development

The Space Product Development (SPD) Program is charged with meeting the goals in NASA's charter and the strategic plan, to enable the commercialization of space. This is accomplished through facilitating the development of commercial products and services derived from the unique properties of space, encouraging NASA-industry technology dual use projects, promoting industry's use of the *ISS* for engineering research, and in supporting commercially funded development of space research infrastructure elements and services. NASA is encouraging industry to seize this opportunity to ensure the continued economic growth of the United States and enable opportunities for new advances, technological understanding, products, and jobs to the public.

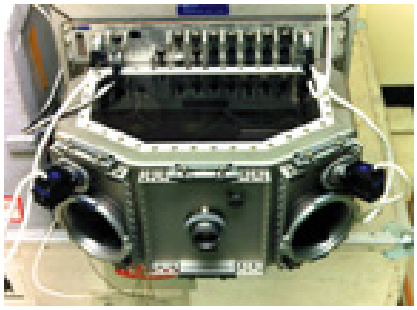
The goals of SPD are to facilitate the use of space for commercial products and services, and to use the unique attributes of space to conduct industry driven research in which materials or knowledge developed in space can be used on Earth for the development or improvement of a commercial product or service.

The SPD program is managed for NASA by the Microgravity Research Program Office at Marshall. The SPD program is primarily implemented through Commercial Space Centers (CSC's). Each CSC is a nonprofit consortium of commercial, academic, and/or government entities. The CSC's follow business leads and commitments to pursue product-oriented research in three major disciplines: materials research and development, biotechnology, and agriculture. NASA's role in this partnership is to provide leadership and direction for the integrated program and to provide flight opportunities that are essential to the success of these efforts.

The CSC's have a unique role in assisting private business' conduct of space research. They demonstrate to industry the values of space research, and provide the expertise essential to successful research in space. CSC's furnish an infrastructure that provides a cost effective and efficient way for industries to conduct research in space. The CSC's initiate industry involvement by identifying and investigating research areas of industry-led commercial promise, and by assessing markets for these potential research opportunities. The

The Light Emitting Diode Cancer Research Project is being nominated for one of *Discovery* magazine's top stories of 1998.

businesses support the research effort with resources including funding, technical expertise, research materials, personnel, ground facilities, and research hardware.



The USML–1 Glovebox is a multiuser facility supporting 16 experiments in fluid dynamics, combustion science, crystal growth, and technology demonstration.

Microgravity Space Product Development Highlights

During FY 1998, many products enabled by SPD have successfully progressed through various stages of development. A new treatment for influenza, developed with the aid of information from space-grown crystals, continues to advance through the drug development and approval process. BioCryst Incorporated, a commercial partner of the Center for Macromolecular Crystallography, has teamed with Johnson and Johnson to develop and market this drug worldwide. Preliminary testing shows the drug to be effective against influenza A and B viruses, with human clinical trials progressing.

Proleukin, developed by Chiron Corporation through partnership with BioServe Space Technologies, has been approved by the FDA for use in treatment of bladder cancer and metastatic melanoma. It is now being used in human clinical trials to test its effectiveness as an adjunct treatment for AIDS. Myotrophin has been submitted by Chiron as a New Drug Application to the FDA for use as a treatment of a neural degenerative disease. The company is also evaluating it as a potential treatment for skeletal disorders, since flight research has demonstrated its effectiveness in preventing the bone reduction that results from space flight.

Chagas disease, a parasite-born disease that affects muscles like the heart, is receiving heightened interest through work done by the Center for Macromolecular Crystallography. New studies made possible by the high quality protein crystals grown on the Shuttle have resulted in significant advances and possible treatments.

Improvements in plant growth Light Emitting Diodes by Quantum Devices has helped advance photodynamic cancer therapy, and improved and extended the lives of children with brain cancer. The Center for Commercial Applications of Combustion in Space has successfully synthesized ceramic metallic composites that may provide a substitute for human bone in replacement surgery.

Ford Motor Company used materials data supplied by the Solidification Design Center (a CSC) to design new, high quality sand molding processes for creating precision automotive parts. This type of work is also being done for ALCOA and Howmet Corporation to help cast parts that are more reliable and have lower production costs. Brush Wellman Incorporated has successfully produced the world's largest aluminum-beryllium casting with the assistance of ground-based casting data and computational models developed by the Solidification Design Center.

A special optical detector developed by the Space Vacuum Epitaxy Center (a CSC) may offer the hope of sight to people with a variety of eye problems. The detector is designed to be implanted on the back wall of the eye to replace natural sensors damaged by disease or accident. It converts light into electrical signals in much the same way as rods and cones do in a healthy eye. The impulses are then picked up by the optical nerve. Preliminary testing has been successful and efforts at commercial development are underway.

Ford and other manufacturers have improved their casting products through commercial microgravity research.

Space Observatories and Space Science

Marshall's involvement with space observatories began in the late 1960's with the development of the Apollo Telescope Mount for Skylab and proceeded through the development of the three High Energy Astrophysics Observatories in the 1970's, the Hubble Space Telescope in the 1980's and the Chandra X-Ray Observatory in the 1990's. During this time they also developed the Burst and Transient Source Experiment on the Compton Gamma-Ray Observatory.

Chandra X-Ray Observatory

The Chandra X-Ray Observatory (CXO) will scrutinize objects in the invisible energy range of x-ray radiation. It will allow us to study the x-ray-producing births and deaths of stars and other, more exotic objects, such as black holes.

MSFC is managing the development and operations of the CXO, formerly referred to as the Advanced X-Ray Astrophysics Facility. The observatory has been renamed in honor of the late Indian-American Nobel Laureate Subrahmanyan Chandrasekhar, who made fundamental contributions to the theory of black holes and other phenomena that the CXO will study.

The CXO is a space-based observatory that will provide a 10-fold gain in resolving power over previous x-ray telescopes. In May 1997 the High Resolution Mirror Assembly (HRMA) completed testing at the MSFC X-Ray Calibration Facility and performed beyond expectations. The HRMA was then delivered to the TRW Space and Electronics Group in Redondo Beach, CA, where the HRMA and the Optical Bench Assembly were integrated into the telescope system.

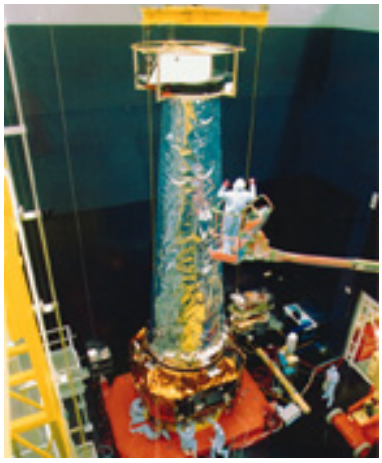
During fiscal year 1998 at TRW, the telescope was integrated with the spacecraft and the Integrated Science Instrument Module, resulting in a completely assembled and integrated CXO. After integration, electrical and system-level testing was initiated which included environmental testing such as acoustic and thermal vacuum tests. The CXO successfully completed these tests which assess performance in the simulated environment to which it will be subjected during the ascent and on-orbit operational phase. During the remainder of the year, activities focused on completing the post-environmental electrical and system-level testing.

Marshall designed, built, and delivered the Operations Control Center (OCC) in FY98. The major focus at the OCC, which is under contract to the Smithsonian Astrophysical Observatory in Cambridge, MA, has been the preparation of the flight operations team and the final preparations of the ground command and control system. It is from the OCC that flight engineers will control the spacecraft, transmit instructions, and receive and process data that are sent back to Earth.

The CXO is scheduled to be delivered from TRW to Kennedy Space Center early in the next calendar year and launched in the summer of 1999. This mission of discovery is planned to last at least 5 years. Once in orbit, the CXO will take its place among NASA's other great observatories.

Space Science

During 1998, Marshall led a team to confirm the magnetar theory. Under this theory, the collapse of a star with an exceptionally strong magnetic field would leave a rapidly rotating neutron star with a magnetic field about 1,000 times greater than that of normal neutron stars. Using satellite instruments, research teams confirmed the existence of the first 2 magnetars, opening a new branch of investigations for the CXO and other instruments.



The Chandra X-Ray Observatory being installed on transporter.

Solar activity was a focus of Marshall scientists in FY98. Research concerning sunspot activity has helped in the understanding of geomagnetic storms, which can disrupt communications and power systems on Earth and affect spacecraft operations. Solar activity also drives the aurora borealis, the curtains of green and red light concentrated in the polar regions. The MSFC Far Ultraviolet Imager on the Polar spacecraft has helped answer questions such as the source and intensity of energy deposited in the auroral zones. Discoveries include a new auroral feature near midnight, the independence of dayside and nightside auroral features, and the auroral response to the Sun's coronal mass ejections.

In 1998, Marshall supported two investigations under NASA's new and innovative Astrobiology Institute. Scientist will look for biomarkers, signs of life in soil and rocks, and develop methods to examine samples so that indications of life or nonlife can be obtained. Researchers use advanced tools such as the Scanning Electron Microscope and atomic-force microscope which are normally used to support engineering.

Space Optics Manufacturing Technology

In 1998, Marshall's mission was expanded to include Space Optics Manufacturing Technology. The focus of the mission is the development of the optics technology required to enable the NASA missions of the 21st century. It involves the areas of fabrication, metrology and testing, and although it supports a broad variety of programs throughout the Agency, it's primarily aimed at supporting the science mission areas of the Goddard Space Flight Center (GSFC) and the Jet Propulsion Laboratory. The mission area leverages an extensive capability at Marshall which includes approximately $100 million in equipment and facilities and 100,000 square feet in facilities devoted to the fabrication and testing of optics.

MSFC has a long history of developing technology for the manufacture of optics for space-based systems going back to the late 1960's when they were developing fabrication techniques for the manufacture of x-ray optics. This led first to the SO–56 X-ray telescope in the Skylab program, then on to the High Energy Astrophysics Observatory Series, and finally to the most recent Chandra X-Ray Observatory. Also developed were techniques for the polishing and figuring of large optics as part of the Large Space Telescope study program, which eventually evolved to become the Hubble Space Telescope.

FY98 activities included supporting the Next Generation Space Telescope (NGST) and Constellation X-Ray Mission (CXM) for the GSFC, and the development of Fresnel and diffractive optics for a number of programs. Optics were also fabricated at Marshall for Cassini's Composite Infrared Spectrometer, the Ultraviolet Imager (UVI), and the Solar X-Ray Imager (SXI). Cassini and UVI were recently launched, and SXI is currently awaiting launch.

Advanced lightweight electro-formed nickel mirror for the NGST.

Next Generation Space Telescope

The NGST is envisioned as an 8-meter diameter telescope operating in the infrared. It will be capable of looking back to a time when the universe was still young, bringing us images of the formation of the first galaxies. Marshall has the responsibility for the development of the optics technologies that will enable this mission. A number of efforts were undertaken during 1998. The NGST Mirror System Demonstrator (NMSD) program involved the development of two technology demonstrations of ultra-lightweight mirrors that, when completed early next year, will result in the largest, lightest mirrors ever to be developed, having areal densities of 15 kilograms per square meter. This is an order of magnitude lighter than the primary mirror for Hubble (2.4-meter diameter). The mirrors are being developed by the University of Arizona (2-meter diameter) and Composite Optics Inc. (1.6-meter diameter). The Advanced Mirror System Demonstrator program was also initiated. This is a historic program involving collaboration between NASA, the Air Force and the National Reconaissance Office. The purpose of this effort is to demonstrate even more advanced lightweight optics than those of the NMSD program. In addition, a number of systems studies were undertaken including the examination of micrometeoroid effects. Technology investigations were also undertaken in different mirror materials including composites, silicon carbides, and metals, particularly electro-formed nickel mirrors. Preparations were also started for the modification of the X-Ray Calibration Facility (XRCF) to accommodate the testing of the NMSD mirrors at cryogenic temperatures (30 degrees Kelvin).

Advanced lightweight electro-formed nickel mirror for the Constellation X.

Constellation X-Ray Mission

The NASA Strategic Plan for the Space Science Enterprise identifies the Constellation X-Ray Mission as a candidate new start for the period 2003–2009. With the completion of the mission-concept study, the project has entered the prephase-A period. Vital to the success of Constellation X is the development of technologies for

achieving lightweight (factor-of-six reduction in mass), high-resolution x-ray optics.

MSFC's full-shell replicated-optics technology program made significant progress toward this objective. The development of an electroplated nickel alloy of exceptional microyield strength, at least an order of magnitude higher than conventional electroplated nickel, and a process for achieving low, uniform shell-to-mandrel interface adhesion contributed to this effort. These two technological advances will allow the required six-fold reduction in weight, while maintaining angular resolution.

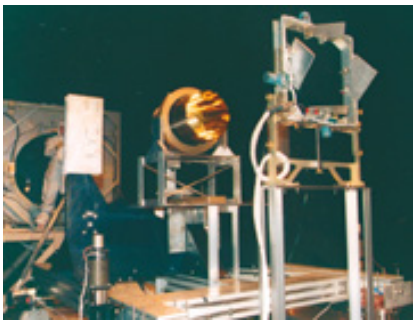
To demonstrate the suitability of this technology for Constellation X requires the fabrication and x-ray testing of large (50- to 160-centimeter diameter) optics. To this end, MSFC has put in place much of the requisite infrastructure including a 4.5-meter diameter e-beam coating chamber, a modified AXAF automatic grinder and polisher to support figuring and polishing of large mandrels, a vertical long trace profilometer for metrology of large mandrels and shells, an upgraded diamond turning machine for large mandrels, and a large plating facility (to be completed in January of 2000) for electroless plating large mandrels and electroforming large shells.

Optical Systems Testing

Marshall's X-Ray Calibration Facility, the largest and most sophisticated laboratory for testing x-ray optics, has the capability to send a single x-ray into a test chamber in order to measure the sensitivity of the cameras or instruments. In 1998 the facility was inducted into the Alabama Engineering Hall of Fame.

A number of x-ray optical performance tests were conducted at the XRCF in FY98. The AXAF/Chandra test series was completed with the final post-test characterization of the x-ray point source. Analysis of Solar X-Ray Imager–M (SXI–M) calibration data indicated large differences with the predicted telescope performance. The SXI–M was recalibrated in February using the XRCF. Test data collected at the XRCF was used to characterize the telescope with the high degree of confidence required to fly the instrument. In the June-July timeframe the XRCF engineering staff, in concert with the Technology Transfer office, worked with students from Brigham Young University to demonstrate the functional performance of their low-cost, student-developed GoldHelox solar x-ray telescope. The instrument was assembled and x-ray optical performance data were successfully collected. The test was a milestone for the GoldHelox project. The first of a series of x-ray characterization tests of replicated optics for the CXM was conducted in September. A gold-coated graphite epoxy mirror built by Dornier Satellite Systems was tested, and preparations for cryogenic optical testing of large space optics were initiated for the NGST. Several facility concepts were studied, specifications developed, and a contract was initiated to procure a helium refrigerator and thermal shroud to provide a 30 degree Kelvin optical test environment.

The X-Ray Calibration Facility located at Marshall.



Testing of advanced graphite epoxy x-ray mirror manufactured by Dornier.

Diffractive Optics

MSFC has recently completed participation in a cooperative Diffractive Optics Technology project sponsored by the Defense Advanced Research Projects Agency. The project was a cooperative effort between five industrial participants, the U.S. Army Aviation & Missile Command (AMCOM), and MSFC. MSFC and AMCOM worked jointly on a contributing task with objectives to search for and identify existing and potential candidate military and space science systems well suited for diffractive optics technology insertion, and to develop a precision diffractive optical "mastering" technique, via direct write electron beam lithography. The team delivered microlens array masters to members for replication and test-bed insertion.

Global Hydrology and Climate Center

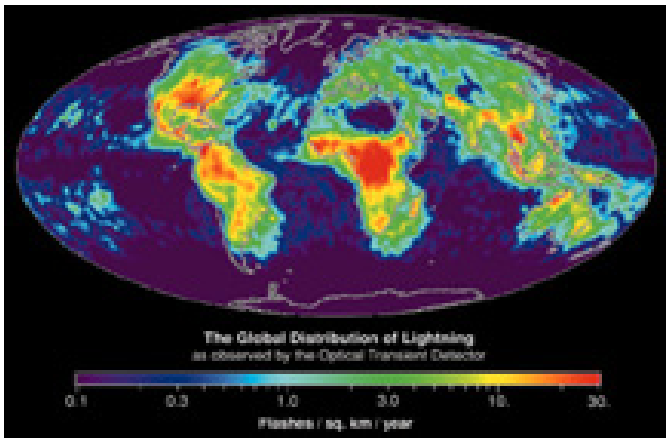
The Global Hydrology and Climate Center's (GHCC's) many areas of study are closely related to each other. Like the climate and environment, no one aspect stands alone, all connect in a complex, interactive Earth-atmosphere system. This is what makes our work both challenging and intriguing. GHCC researchers are working together toward a future of improved hurricane and severe storm prediction, more reliable day-to-day weather forecasts, and better urban planning.

Preliminary design was completed for SPAce Readiness Coherent Lidar Experiment (SPARCLE).

Researchers at the GHCC have created several important climatic datasets. The longest of these is a 20-year dataset of global temperature change from the Microwave Sounding Unit. Also created were 1 year of tropical lightning data measured by the Lightning Imaging Sensor on board the Tropical Rain Measuring Mission satellite, and 3 years of global lightning data compiled from the Optical Transient Detector aboard the Micro-Lab 1 satellite. The lightning detectors are helping to pave the way for a future space-based lightning mapper. The future mapper could deliver day and night lightning information to a forecaster's workstation within 30 seconds of occurrence—providing an invaluable tool for storm "nowcasting" and giving people more advance warning of severe storms.

As part of an Atlantic hurricane and tropical storm study, CAMEX–3, a NASA crew flew a DC–9 aircraft into the eye of Hurricane Bonnie for purposes of weather research. The GHCC provided the science lead as well as several instruments to the study. Preliminary design was completed for SPAce Readiness Coherent Lidar Experiment (SPARCLE), a Space Shuttle demonstration of Doppler wind lidar technology. GHCC researches are studying some of the country's "hottest" cities. They are using thermal images to pinpoint a city's hot spots. The images are being used to improve urban planning and tree planting plans. The researchers believe strategically placed "urban forests" and reflective surfaces may help cool cities, reduce pollution and lower energy bills. The efforts of GHCC personnel resulted in a Memorandum of Understanding between NASA and Central American Commission on the Environment and Development (CCAD) which was signed by Dan Goldin to conduct cooperative remote sensing research for a biological corridor throughout Central America.

GHRC produces global summaries of lightning strikes.



Institutional Highlights

In 1998, MSFC implemented several institutional initiatives which supported the NASA Strategic Plan and the MSFC policy to provide quality products and services to our customers. MSFC's commitment to safety, to the organization of policies and standards, implementation of a "process" approach for management of all programs, acceptance of accountability for all resources, and MSFC compliance with various Federal requirements are highlighted in the following examples.

Safety

In September 1998, Marshall marked a work stand-down to dedicate the entire day to safety awareness. With the exception of mandatory services such as fire, security, and cafeterias, all work was suspended to allow personnel to attend Safety Day activities. During the day employees viewed local safety vendor products at a Safety and Health Fair. Visiting astronauts and Center Managers participated in informal tours of the Center. Employees attended planned organizational activities where they were challenged to consider how their jobs affect the safety of flight hardware, how their work environment could be safer, and how to improve their personal safety. Center Management is committed to total involvement of the MSFC workforce in eliminating mishaps at work and away from work.

In FY98 Marshall initiated the Neighborhood Watch program. This program assigned management accountability for every space at MSFC and established an area committee for oversight of safety, environmental health, and environmental management.

To assure continued improvement Marshall contracted with DuPont, the world leader in safety management, to assess and benchmark the MSFC safety program against the DuPont system. Resulting initiatives include a new safety organizational committee structure chaired by the Center Director, augmented training to implement safety focus which ensures line management and employee responsibility and accountability, and a line management safety auditing program.

International Organization of Standards (ISO 9001)

In February of 1998, MSFC was certified to the ISO 9001 Standard of the International Organization of Standards. This certification applies to all on-site processes for procurement, design, development, and onsite production of flight hardware, flight software, and associated ground support equipment interfacing with

The NAIS continued to "push the envelope" in pioneering the internet for the federal acquisition process in 1998.

flight hardware and software. Marshall has received one Registrar Surveillance since the February registration with no major problems identified. With the success of implementing ISO at MSFC and as a result of the benefits received, MSFC Management has decided to expand the scope of the ISO management system to include all activities here as well as off-site locations. MSFC's increased registration goal is May 2000.

NASA Program and Project Management

The April 1998 implementation of NASA Program and Project Management Processes and Requirements (NPG 7120.5A) was a milestone revision to an existing NASA Handbook (NHB 7120.5) which described how to manage major programs and projects within NASA. The revision of this document describes a "process" approach, which defined what must be accomplished to manage our programs and projects. The revision defined guidelines and requirements that could be applied to any NASA program or project that provide aerospace products or capabilities (i.e., space and aeronautics, flight and ground systems, technologies, and operations) consistent with size, complexity, criticality, and risk and be utilized within the operating framework of any NASA Center. MSFC made significant contributions to the writing, review, and finalization of NPG 7120.5A through MSFC's assignment to chair the Program Management Council Working Group (PMCWG) which reports to Jack Dailey, Chairman of the NASA Program Management Council and NASA Deputy Administrator. The PMCWG included members from several NASA Headquarters Offices and Centers. The implementation of NPG 7120.5A across the Agency since its approval has been extensive. Every NASA Center has been given a presentation by a team of Senior NASA Managers lead by the NASA Deputy Administrator. In addition, a one and one-half day training course is currently being presented at every NASA Center.

The Marshall Space Flight Center made major contributions to the success of this Agencywide activity through the leadership of its senior management, contributions of numerous program and project managers within the Center, and our role as a leader in developing program/project training initiatives.

Earned Value Management (EVM)

The Government Performance and Results Act (GPRA) requires greater accountability for expenditures of the Federal Budget. EVM has been recognized by the Office of Management and Budget (OMB) as the primary means for Project Managers to establish baseline goals and measure cost, schedule, and technical variances against them. In August 1996, MSFC was awarded the Agency Lead Center Responsibility for EVM. MSFC conducted a successful Agencywide EVM Workshop in 1998 to discuss EVM policy, procedures, and training initiatives. The EVM Focal Point Council, consisting of representatives from all NASA Centers, will continue its efforts to implement EVM in a consistent manner across the Agency in FY99.

Integrated Financial Management Program

During 1998 MSFC continued to work toward the implementation of NASA's Agencywide Integrated Financial Management (IFM) System. The IFM System will provide Agency financial and procurement standardization currently required by Federal Regulations and Policies.

NASA Acquisition Internet Service

The NASA Acquisition Internet Service (NAIS) continued to "push the envelope" in pioneering the Internet for the Federal acquisition process in 1998. After a long and demanding audit, NASA's electronic commerce model gained a strong endorsement by the General Accounting Office (GAO) and the Administrator of the Office of Federal Procurement Policy (OFPP) within the Office of Management and Budget (OMB). Consequently, a major Federal-wide deployment of this model, to advertise business opportunities and solicit contract offers over the Internet, is now underway. Moreover, the OFPP is pursuing legislative relief from current mandatory waiting periods in the solicitation phase, which were written around the old, paper-based process. This relief should serve as the incentive encouraging other Federal agencies into the newlychartered territory with NASA.

The Agencywide service, under the leadership and technical expertise of MSFC, continued to achieve successes in 1998. The NAIS team deployed its second pilot enabling industry responses to solicitations. The Agency is now testing two

approaches for receiving industry responses, including a web-based forms process allowing vendors to quote on-line for agency requirements of commercial products, and a secured, on-line process allowing prospective offerors to submit business-sensitive proposals with digital signatures. In addition, the MSFC technical team developed and implemented an on-line tool enabling the procurement staff throughout the Agency to share contract services among the Centers under the Consolidated Contracting Initiative (CCI). For example, a Center can use the CCI application to identify and coordinate the use of a planned or existing contract for paper-copying services administered at another Center, thereby avoiding a time-consuming procurement cycle.

Year 2000

Year 2000 (Y2k) has been a major focus of MSFC during the year. Significant progress was made in making Marshall Y2k compliant. Many of the administrative and the science and engineering applications were renovated, validated and implemented. The Agencywide legacy applications, for which MSFC has sustaining engineering responsibility, were also renovated, validated and implemented. All of the data reduction systems were included. Significant progress was also accomplished in making the desktop computers Y2k compliant. MSFC is the lead center for IBM Mainframe computing and Principle Center for Communications Architecture (PCCA). Many commercial off-the-shelf software products were validated for these areas.

Outsourcing Desktop Initiative in NASA (ODIN)

In 1997 the Agency committed to a consolidated outsourcing initiative for Information Technology (IT) services. In 1998 these services were competed and on October 30, 1998, OAO Corporation of Greenbelt, MD, was selected to provide IT services for the four Office of Space Flight Centers under ODIN. This is a firm fixed price delivery order contract and the period of performance for the Marshall Center is May 1, 1999, through November 30, 2001. The total value of MSFC's delivery order is $41.7 million. The services for MSFC include comprehensive desktop computer, server, and local area networks.

Digital Television (DTV)

The Federal Communications Commission (FCC) adopted a DTV transmission standard in December 1996. In April 1997, the FCC issued a transition schedule which calls for DTV transmission to begin in 1999 with analog transmission ending in 2006. MSFC has the lead responsibility for the Agency's transition to DTV. In 1998 MSFC led the establishment of a NASA-wide DTV working group with representation from each Center, Headquarters, and the Space Shuttle and Space Station Programs. The working group collects and reviews technical requirements, budget estimates, industry standards, and architecture recommendations. In addition, the working group coordinates activities between programs and Centers, and advises senior Agency management. A Program Commitment Agreement (PCA) and Program Plan have been prepared and are pending approval. Once approved, it requires implementation of DTV at each Center by 2004, with emphasis on a capability for acquiring, editing, and distributing DTV to the media, and implementation of DTV from on orbit. The PCA calls for each Enterprise and Center to establish an initial DTV production capability at each Center, Headquarters, and the Jet Propulsion Laboratory as early as 2000 and to complete the effort no later than 2004. In 1998 an initial schedule was established and funding requirements identified. Individual implementation plans have been submitted for initial DTV capability which will in turn refine the DTV schedule and funding sources.

In 1998 MSFC led the establishment of a NASA-wide DTV working group with representation from each Center, Headquarters, and the Space Shuttle and Space Station Programs.

Public Outreach

Marshall is one of NASA's premier Centers. Our employees and world-class facilities make Marshall a true, national resource. With our roots linked to Wernher von Braun's rocket team of the past, the people of Marshall are continuing to reach for the stars to better understand the universe and the world we live in.

Marshall is the world leader in providing access to space and in the use of space for research and development to benefit humanity. Through the everyday efforts of a dedicated workforce, the Center is striving to keep America the world's leader in space transportation and space sciences making life better for all of us here on Earth.

The following information is provided to inform readers about some of the many benefits currently coming from the United States space program and about the contributions the Center is making for America's future. Technologies that take us to the stars today are the engines that drive America's future.

Understanding Earth's Climate-GoldHelox Telescope

Brigham Young University students in Provo, UT, understand what it is like to see something through from beginning to end. More than a decade of effort by over 200 students culminated this summer as students worked with MSFC engineers to prove their solar telescope worked. The telescope is called GoldHelox—a name that comes from the Sun's golden color and its ability to make heliocentric observations in x-rays. It is designed to be flown aboard a future Space Shuttle mission. Aboard the Shuttle, the telescope can detect solar x-rays obscured by the Earth's atmosphere. The tests at Marshall showed GoldHelox optics will detect x-rays and image them on film. The GoldHelox science objective is to detect x-rays emitted during solar flares and observe other solar activities that affect Earth. Variations in solar activity influence Earth's climate and weather patterns and can damage both space-and ground-based communications and power systems.

Digital Data Matrix—Next Generation Bar Codes

Today, when a defect in a particular batch of auto parts is discovered, it becomes necessary to recall thousands of vehicles for inspections. With digital data matrix identification, the vendor has all the information needed to determine accurately and automatically the extent of the recall. Digital data matrix technology used to identify the millions of Space Shuttle parts is being commercialized to make barcoding tamper resistant and invisible to the naked eye. This technology can fill a growing commercial industry need as an identification system that can be applied directly to a product, regardless of shape, size, or color. The markings can range from as small as 4 microns to as large as 2 square feet. The invisible and virtually indestructible laser-etched markings are seen as the next generation of the product bar codes.

Technology to Clean Up Oil Spills

An Alabama hairdresser's flash of inspiration may hold the key to future oil spill clean-ups. The inspiration led to the idea of using human hair to clean up major oil spills. The hair-

dresser, also the President of BEPS, Inc., first tested the technique using a small swimming pool, used motor oil, and a pair of pantyhose stuffed with human hair. Under terms of a Space Act Agreement, MSFC collaborated with BEPS, Inc. of Madison, AL, to officially test the novel technique. Initial testing was done by Marshall contractor BAMSI, Inc., using a 55-gallon drum containing 40 gallons of water and 15 gallons of oil. In a single pass of the hair, the water contained no more than 17 parts per million of oil. The U.S. Environmental Protection Agency allows discharge of water that has 15 parts per million of oil. There is also a potential cost savings in the new method. Present techniques cost approximately $10 to recover a gallon of oil. This system may cost as little as $2 per gallon and offers the additional benefit of being able to use the recovered oil for fuel.

VISAR—Clear Video Imagery

Law enforcement officials around the country may soon have help when solving crimes. Video Image Stabilization and Registration (VISAR), a MSFC technology, is a new concept in clear video imagery. The VISAR technology improves the clarity of video footage by correcting distortion caused by adverse conditions. This technology stabilizes camera rotation and zoom effects, produces clearer images of moving objects, smoothes jagged edges, enhances still images and reduces video noise or snow. After the footage has been cleaned up it can be further enhanced through sharpening and de-blurring techniques. In a demonstration, VISAR was able to accurately clarify a license plate of a car involved in a car chase. Marshall's Chief Council has filed a provisional patent for VISAR and the Technology Transfer Office is now seeking to commercialize the technology via licenses to U.S. companies.

Fastrac—American-Made Engine—Better, Faster, Cheaper

Fastrac is only the second American-made rocket engine developed in the last 25 years. It is a true reflection of NASA's new philosophy of better, faster, cheaper. It is designed to cost approximately one-fifth of the cost of other engines of similar size and performance. NASA envisions use of the Marshall designed engine for both NASA mission needs and commercial markets.

Technology Transfer

Through the Technology Transfer Program, NASA employs a variety of mechanisms to transfer aerospace technology to other sectors of the economy. The benefits of technology transfer touch each of us every day. Whether it be advances in medical research, improvements in environmental protection, or gains in energy conservation, our alliances with the private sector have a profound effect on our quality of life.

BizTec—Business TechnologyDevelopment Center

It is tough to get a business up and running, but with a little help even the smallest company may survive. Marshall Space Flight Center has partnered with Business Technology Development Center, Inc. (BizTech) to nurture small, high-technology oriented businesses through their vulnerable years. BizTech is a not-for-profit business incubator and is supported by an alliance that provides matching funds to construct and operate the incubator. In addition to Marshall, other members of the alliance include the Tennessee Valley Authority (TVA), the State of Alabama Department of Economic and Community Development (ADECA), and the City of Huntsville. The incubator provides an affiliate program for nonresident clients and a mentoring program. Marshall is helping to nourish and encourage the growth of new, high technology firms in Huntsville and Madison County through its partnership and financial support of BizTech.

Socioeconomic Programs

The Socioeconomic Program is a function within the MSFC Procurement Office. This office plans, implements, and administers the socioeconomic programs to advocate contracting diversity. During FY98, MSFC achieved all of its socioeconomic goals. Its performance against the goals are small business direct (141.1 percent of goal), small disadvantaged business direct (136.9 percent of goal), woman-owned business direct (132 percent of goal), small business subcontracting (100.2 percent of goal), small disadvantaged business subcontracting (115.5 percent of goal), and, woman-owned subcontracting (131.3 percent of goal). The Agency's congressional goal is 8 percent. MSFC reached the 10 percent level during FY98 and this is the first time to reach the double digit level.

Special initiatives implemented in 1998 included the Suppliers Street Market, a marketing method whereby small suppliers display their products/services at the Center and gain exposure to the internal purchasing market, especially the growing credit card purchasers. Also initiated was a Small Business Introduction Review Forum for developing businesses. New businesses are introduced to the Center at the MSFC Small and Minority Business Council meetings. The Council membership is the senior management and directorates of the center. Five small businesses were profiled and reviewed in this forum.

The Morphis Movie Ride was a hit, attracting long waiting lines at the MSFC Open House.

Significant increases in the level of subcontracting goals were included in new subcontracting plans this year. A key to improved subcontracting opportunities for targeted business groups was the factoring of goals on contract value.

Significant outreach activity for the year was the Southeastern Area Small Business Council Sunshine Small Business Fair, the National Contract Management Association World Congress Expo, and support of the Minority Enterprise Development week.

Open House

On May 16, 1998, more than 26,000 people took a special look inside the Marshall Center, where dreams leap from drawing boards and rocket into space. Guests journeyed deep inside the labyrinth of Marshall laboratories and test facilities for a rare glimpse of where Marshall scientists and engineers turn their dreams into reality, using space exploration to improve the health and quality of life for people on Earth. Memorabilia, photos, and commemorative items were on display in celebration of the 25th anniversary of Skylab, America's first space station. Astronauts were available throughout the day for autograph signing and to answer questions asked by our guests. A one-of-a-kind space ride called "Morphis" took riders to Mars and beyond. Live test firings shook the ground under guests' feet routinely during the day. There were miniature rocket launches and a robot who roamed about striking up a conversation with anyone who would talk with him.

Open House guests push buttons that make things happen at Marshall.

Educational Programs

In its more than 38-year history, the Marshall Center has always placed a high priority on education, both with students in the community, throughout the country and with our employees. Our support of the educational community is looked upon as an investment in America's future.

In its educational programs, the Marshall Center endeavors to support and facilitate the educational community by providing content and services which furnish access to and meaningful involvement in NASA missions and consequently its achievements. We involve the educational community in our endeavors to inspire America's students, create learning opportunities, and enlighten inquisitive minds. These efforts are directed toward ensuring the continued availability of scientists and engineers required to preserve our leadership in aerospace science and technology.

In FY98, the Marshall Center involved academia through its formal educational programs and services. MSFC's educational programs cover the spectrum from elementary school to graduate school and beyond. In FY98, we directly touched more than 416,774 students, 42,685 educators, and 663 institutions in 50 states through the operation of our programs. Also $6.73 million of research equipment was donated and $125 million was awarded through grants, contracts and cooperative agreements. One hundred-fourteen research grants totaling $24 million were awarded to Alabama institutions. We now have in place program objectives that ensure we maximize our limited resources and expand the delivery of programs and materials to the broadest possible audience through appropriate use of educational technologies.

NASA Spacelink, NASA's electronic resource for educators, is operated from MSFC. The system, designed

primarily for educators, is available through the World Wide Web. During any given month, Spacelink receives over 4 million "hits" and routinely delivers over 21 gigabytes (GB) of documents, images or other electronic files. Users of Spacelink range worldwide.

Educator Resource Centers (ERC's) are located near or on NASA Field Centers, and offer a variety of NASA-related educational materials in several formats. The MSFC ERC is located at the Space and Rocket Center. During FY98, 8,282 educators benefited from the ERC resources, and 144,749 educational publications were mailed to educators.

A 1998 teacher workshop in the ERC located at the U.S. Space and Rocket Center in Huntsville, AL.

- **PreCollege Programs—**The **Project LASER (Learning About Science, Engineering and Research)** program recorded 352 instances of MSFC volunteers making presentations, holding workshops, serving as science fair judges, conducting tours of MSFC facilities, and being study buddies and mentors for students with special needs and/or interests. Through these volunteers 15,834 students, 1,266 educators from 14 institutions in 2 states were effected. The Project LASER program is available for preschool through high school students and teachers, including a special class for high school hearing impaired students.

  The **Aerospace Education Services Program (AESP)** provides the services of a specialist in aerospace education to schools and educational organizations. The specialist typically spends a day at a school conducting educational presentations and space-related demonstrations to students. Specialists are also available to participate in teacher workshops and in-service programs. During FY98, education specialists from the Marshall Center conducted programs to 29,347 students, and 2,153 teachers at 200 institutions in 10 states. In March, AESP supported Alabama Aerospace Week, a week-long emphasis on aerospace education sponsored by the Alabama Education Association. NASA education specialists visited 39 schools in the state.

  The **Summer High School Apprenticeship Research Program (SHARP)** is a NASA-wide, research-based, mentored program, specifically designed to increase qualified underrepresented high school students an opportunity to participate in an intensive science and engineering apprenticeship program. Students selected must have shown an aptitude for and an interest in science and engineering careers. The 9-week program offers the students an opportunity to learn and earn. During fiscal year 1998, 32 students representing 13 institutions in Madison County, AL, participated in the apprenticeship program.

  NASA Educational Workshop for Mathematics, Science, and Technology Teachers (NEWMAST) is conducted each summer. In FY98 25 teachers representing 13 states participated in this 2-week on-site program. Program participants visited MSFC research and development laboratories where they gained insight to help develop and enhance science and mathematics instructional skills.

- **University Programs—**The **Annual Moon Buggy Competition** gives undergraduate and high schools students from around the nation an opportunity to apply engineering skills, and it enhances awareness about human exploration and development of space. Each team builds a moon buggy from their own design, recreating the lunar experience of the Apollo astronauts and looking ahead to further human explora-

1998 spaceweek activities with astronaut Roger Crouch at East Clinton Elementary School.

1998 Moon Buggy Race at the U.S. Space and Rocket Center in Huntsville, AL.

tion of the solar system. During FY98 there were 16 competing teams, consisting of 80 students (3 high schools, 8 undergraduate), and 23 educators (3 high school, 8 undergraduate) representing 11 institutions in 10 states.

The **Graduate Student Researchers Program (GSRP)** awards fellowships each year to promising U.S. graduate students whose research interests coincide with NASA's mission. MSFC awarded 39 GSRP fellowships involving 15 institutions in 11 states during FY98; 11 of those awards went to students enrolled in Alabama institutes of higher education.

The **Summer Faculty Fellowship Program (SFFP)** awards research fellowships to university faculty through the NASA/ American Society for Engineering Education SFFP. The 1998 MSFC program had a total of 72 participants from 40 institutions and 21 states. Six faculty from Alabama universities were participants.

Space Grant Colleges/Consortia have been designated to provide leadership and form partnerships with other universities, government and industry to better understand, develop, and use space resources through research, education, and public service functions. Alabama Space Grant Consortium funding was approximately $248,500 with 41 students and 6 Alabama universities participating.

The **National Research Council** conducts a national competition to identify outstanding recent postdoctoral scientists and engineers and experienced senior scientists and engineers for tenure as guest researchers at NASA Centers. In 1998, the MSFC had 11 Resident Research Associates working at the Center.

The **NASA/University Joint Venture (JOVE)** Program is a partnership between NASA and institutions of higher education. It is designed to include liberal arts colleges, and public and private universities throughout the U.S. In 1998 there were 100 educators, and 183 students representing 67 institutions in 36 states. Four Alabama colleges were involved in the JOVE Program.

- **Education Alliances**—Educational alliances are responsible for using NASA's unique assets to support all types of learning by collaborating with nonprofit educational organizations and business partners. We provide educational programs and exhibits at the Center for Biospheric and Educational Research (CeBER), located at the Huntsville and Madison County Botanical Garden. A number of Marshall employees serve as volunteer guides and instructors at the North Alabama Science Center, a hands-on educational museum that opened its doors in early 1997. We support exhibits, tours, and Space Camp programs at the U.S. Space and Rocket Center; we provide special instruction programs for the Huntsville City Schools' New Century Technology Demonstration High School; we help develop and distribute science learning materials through the Hands-on Alliance for Science Project (HASP); we conduct workshops throughout Alabama for NASA's Global Learning and Observations to Benefit the Environment (GLOBE) program; and we are active participants in the Huntsville-Madison County Chamber of Commerce efforts to involve local businesses in the effort to improve our educational system and celebrate American Education Week. All of our partnership efforts are driven by the Marshall Center's commitment to serve the community.

Marshall's Economic Contributions

Marshall in Huntsville contributed $722 million to Alabama's economy during FY98 that ended last September. This figure includes $223 million in salaries for civil service personnel and related costs, and travel. It also includes $499 million spent on locally procured services, prime and subcontractor support, local construction and reimbursable activities performed for other Federal agencies, private industry, and foreign governments. In addition, approximately $66 million in retirement annuities were paid to 2,511 Marshall retirees residing in

Alabama, with some $39 million of that going to 1,487 retirees living in Huntsville. Additional NASA funding (approximately $220 million) was spent locally for *ISS* hardware development by Boeing-Huntsville. During fiscal year 1998 the Marshall Center received approximately 17 percent of NASA's total budget of $13.6 billion. Of Marshall's $2.3 billion allocation, $1.26 billion was spent for Human Space Flight activities, $687 million went for Science Aeronautics and Technology, and the balance—$380 million—was spent on mission support at Marshall and other sites across the country. The $722 million spent in Alabama by the MSFC was more than its expenditures in any other state. California received approximately $568 million, $313 million was spent in Utah, $287 million was spent in Louisiana and $132 million in Florida. Smaller sums were distributed among other states. Since it was established in 1960, the Marshall Center has had budget responsibility for a total of $62.6 billion. When year-by-year figures are adjusted for inflation, this total is equivalent to more than $161 billion in 1998 dollars.

The Marshall Center has paid $4.6 billion in Federal salaries during the past 38 years. During FY98 there were 2,822 civil service employees working to support Center work. During the past fiscal year, approximately 25,106 contractor personnel were engaged in work for the Center, including 2,753 in mission support; 9,539 on prime contract work; and 12,814 as subcontractors and vendors. Of the total, 6,404 work in Alabama. An additional 1,606 contractors were associated with *International Space Station* work being done by Boeing in Huntsville, and other Agency contracts not previously mentioned.

In FY98, 203,493 individuals toured MSFC including educators, civic, conference and symposia visitors, and news media. Of these visitors, 170,557 toured the Center as part of the Space and Rocket Center's bus tour program. An additional 26,000 visitors toured the Center on May 16, 1998, as Marshall opened its doors to the public. Marshall's employees pledged $442,004 to the Combined Federal Campaign in 1998, with $253,501 designated for agencies in Alabama. These figures do not include contributions from Marshall retirees or contractor employees who contributed directly to the United Way Campaign.

Marshall employees paid approximately $6.1 million in Alabama state income taxes and $30 million in Federal income taxes in fiscal year 1998.

Other Facts About MSFC in FY98:

In December 1997, the Marshall Contractor Excellence Awards for 1997 were presented to Boeing/Rocketdyne, Distributed Information System, Boeing/McDonnell Douglas, Sverdurp and Summa Technology.

In January 1998, Marshall joined with the NASA in observing the Agency's 40th anniversary. Officially NASA was formed on October 1,1958, and designated to manage the U.S. space program.

MSFC's X-Ray Calibration Facility was inducted into the State of Alabama Engineering Hall of Fame in February 1998.

Marshall was selected as the first National Society of Black Engineers Golden Torch Award winner in March 1998. The award was based on Government Diversity Leadership.

And in September 1998, Dr. Wernher von Braun, who served as the first director of the Marshall Center from 1960 to 1970, was inducted into the Alabama Men's Hall of Fame at a ceremony in Birmingham, AL.

WWW

Visit the following web sites for additional information. Other site listings can be found through the NASA/MSFC homepages.

The NASA Homepage:
http://www.nasa.gov/

The MSFC Homepage:
http://www1.msfc.nasa.gov/

The NASA CFO Homepage:
http://ifmp.nasa.gov/codeb/

The MSFC CFO Homepage:
http://www.msfc.nasa.gov:80/online/cfo/cfo.html

MSFC Education Programs Homepage:
http://www.msfc.nasa.gov/education/

NASA Spacelink:
http://spacelink.msfc.nasa.gov/.index.html

NASA Solutions—Technology Transfer:
http://techtran.msfc.nasa.gov/

Liftoff to Space Exploration:
http://liftoff.msfc.nasa.gov/

Overview of Financial Statements

MSFC's financial statements were prepared in accordance with Federal accounting standards. At present, MSFC observes the following hierarchy of accounting standards as required by the Office of Management and Budget (OMB):

a. Individual Federal Accounting Standards Advisory Board (FASAB) standards published by OMB, GAO, and Treasury

b. OMB financial statement form and content guidance

c. Agency accounting guidance which represents prevalent practice

d. Accounting principles published by other authoritative sources.

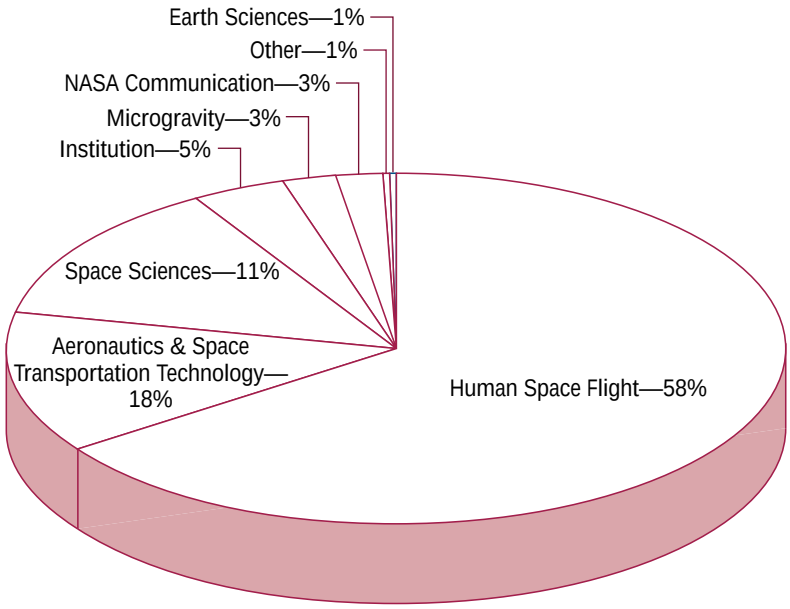
The financial statements include the Statement of Financial Position and the Statement of Operations and Changes in Net Position. These statements include all MSFC activities and 100 percent of the Center's budget authority. While the statements have been prepared from the books and records of MSFC, in accordance with formats prescribed by OMB Bulletin 94-01, the statements are different from the financial reports used to monitor and control budgetary resources which are prepared from the same books and records.

The statements should be read with the realization that they are for a component of a sovereign entity, that liabilities not covered by budgetary resources cannot be liquidated without the enactment of an appropriation, and that payment of all liabilities, other than for contracts, can be abrogated by the sovereign entity.

NASA's budget was funded by three appropriations. The Human Space Flight (HSF) appropriation provides funding for the *International Space Station* and Space Shuttle programs, including flight support for cooperative programs with Russia. The Science, Aeronautics and Technology (SAT) appropriation provides funding for NASA's research and development activities, including all science activities, global monitoring, aeronautics, technology investments, education programs, mission communication services, and direct program support. Funding for NASA's civil service workforce, space communication services, safety and quality assurance activities, and facilities construction activities, to preserve the Agency's core infrastructure, is provided by the Mission Support (MS) appropriation.

Beginning with the fiscal year 1995 budget, the HSF, SAT, and MS appropriations replaced the four appropriations that were previously used to fund NASA's activities. Those appropriations were Space Flight Control and Data Communications (SFCDC), Research and Development (R&D), Research and Program Management (R&PM), and Construction of Facilities (CoF). The fiscal year 1998 Center budget is presented at right.

MSFC FY98 Budget ($M)



Total Budget—$2,330M

Program	$M	% of Total
Human Space Flight	1,340	58%
Aeronautics & Space Transportation Technology	413	18%
Space Sciences	264	11%
Institution	125	5%
Micrograviy	64	3%
NASA Communication	76	3%
Other	15	1%
Earth Sciences	35	1%
Grand Total	**2,330**	**100%**

Note: Civil Service salaries (by rate) included with programs.

Source: FY98 Data—FY00 Budget to Congress, February 1999.

Marshall Space Flight Center Statement of Financial Position
As of September 30, 1998 (In Thousands)

	1998	1997	1996
Assets			
Intragovernmental Assets:			
Fund Balance with U.S. Treasury (Note 2)	$997,599	$1,177,434	$1,215,524
Accounts Receivable, Net (Note 3)	7,413	5,043	2,835
Advances and Prepayments	572	326	666
Governmental Assets:			
Accounts Receivable, Net (Note 3)	38	15	15,933
Advances and Prepayments	0	0	0
Cash, Imprest Fund	0	0	0
Operating Materials and Supplies (Note 4)	2,437	2,627	2,970
Property, Plant and Equipment (Note 5)	3,982,835	5,104,235	4,591,308
Other Assets (Note 6)	1,079,390	1,086,267	907,913
Total Assets	**$6,070,284**	**$7,375,947**	**$6,737,149**
Liabilities			
Liabilities Covered by Budgetary Resources:			
Intragovernmental Liabilities:			
Accounts Payable	$13,370	$21,886	$75,135
Other Liabilities (Note 7)	2,328	510	309
Governmental Liabilities:			
Accounts Payable	613,968	711,280	567,466
Other Liabilities (Note 7)	12,375	11,561	12,412
Total	642,041	745,237	655,322
Liabilities Not Covered by Budgetary Resources:			
Intragovernmental Liabilities:			
Other Liabilities (Note 7)	432	20	23
Governmental Liabilities:			
Other Liabilities (Note 7)	20,738	23,988	25,152
Total	21,170	24,008	25,175
Total Liabilities	**663,211**	**769,245**	**680,497**
Net Position			
Unexpended Appropriations	363,574	437,575	579,620
Invested Capital	5,064,661	6,193,129	5,502,191
Cumulative Results of Operations	0	0	0
Future Funding Requirements	(21,162)	(24,002)	(25,159)
Total Net Position (Note 8)	**5,407,073**	**6,606,702**	**6,056,652**
Total Liabilities and Net Position	**$6,070,284**	**$7,375,947**	**$6,737,149**

The accompanying notes are an integral part of these statements.
These statements are for internal use and have not been audited.

Statement of Operations and Changes in Net Position for the Year Ended September 30, 1998 (In Thousands)

	1998	1997	1996
Revenues and Financing Sources			
Appropriated Capital Used	$2,178,816	$1,882,853	$1,794,240
Revenues from Sales of Goods and Services			
To the Public	13,750	13,772	16,829
Intragovernmental	8,596	14,431	19,666
Other Revenues and Financing Sources (Note 9)	2,554	233	1,225
Less: Receipts Transferred to Treasury	(2,554)	(233)	(1,225)
Total Revenues and Financing Sources	**2,201,162**	**1,911,056**	**1,830,735**
Expenses			
Program or Operating Expenses			
Science, Aeronautics and Technology	$504,403	$651,442	$591,913
Human Space Flight	1,258,506	852,739	824,237
Mission Support	413,048	370,285	336,154
Research and Development	1,217	1,850	18,748
Space Flight Control & Data Communication	(811)	263	10,188
Research and Program Management	0	(41)	(195)
Construction of Facilities	2,453	6,315	13,195
Reimbursable Expenses	22,346	28,203	36,495
Total Expenses	**2,201,162**	**1,911,056**	**1,830,735**
Excess (Shortage) of revenues and Financing Sources Over Total Expenses	0	0	0
Nonoperating Changes			
Unexpended Appropriations	(74,001)	(142,045)	22,932
Invested Capital	(1,128,468)	690,938	20,050
Future Funding Requirements	2,840	1,157	(2,735)
Total Nonoperating Changes	**(1,199,629)**	**550,050**	**40,247**
Excess (Shortage) of Revenues and Financing Sources Over Total Expenses and Nonoperating Changes	(1,199,629)	550,050	40,247
Net Position, Beginning Balance	**6,606,702**	**6,056,652**	**6,016,405**
Net Position, Ending Balance	**$5,407,073**	**$6,606,702**	**$6,056,652**

The accompanying notes are an integral part of these statements.
These statements are for internal use and have not been audited.

MSFC Notes to Financial Statements

for the Year Ended September 30, 1998

1 Summary Accounting Policies and Operations

Basis of Presentation

These financial statements were prepared to report the financial position and results of operations of MSFC, pursuant to the requirements of the Chief Financial Officer's Act of 1990. The statements were prepared from the books and records of MSFC, in accordance with the comprehensive basis of accounting specified in OMB Bulletin 94–01, Formats and Instructions for the Form and Content of Agency Financial Statements.

Reporting Entity

MSFC is one of nine NASA Centers and Headquarters established to aid NASA in its mission to provide for aeronautical and space activities. Financial management of its operations is the responsibility of Center officials at all organizational levels. MSFC's accounting system is one of 10 distinct operations located at 9 NASA Centers and Headquarters. Although MSFC, like the other Centers, is independent and has its own Chief Financial Officer, it operates under Agencywide financial management regulations. MSFC provides payroll accounting Agencywide for approximately 19,000 civilian employees and processes approximately 50,000 nonpayroll-related accounting transactions monthly. This data provides the basic information necessary to meet internal and external financial reporting requirements and provides both funds control and accountability.

Budgets and Budgetary Accounting

Seven appropriations require individual treatment in the MSFC accounting and control system.

1. The HSF appropriation supports human space flight research and development activities for space flight, spacecraft control, and communications actions. This includes research, development, operations, services, maintenance, and construction of facilities which encompasses the repair, rehabilitation, and modification of real and personal property.

2. The SAT appropriation provides for the conduct and support of science, aeronautics, and technology. This includes research, development, operations, services, maintenance, and construction of facilities which encompasses the repair, rehabilitation, and modification of real and personal property.

3. The MS appropriation provides for safety, reliability, and quality assurance activities supporting Agency programs, space communication services for NASA programs, salaries and related expenses in support of research in NASA Field Centers, and construction of facilities which encompasses the repair, rehabilitation, and modification of real and personal property.

4. The R&D appropriation, which was restructured and replaced in the 1995 budget, includes research and development of aeronautics and space, space vehicles, space systems effort, related institutional activities, minor construction repair, maintenance, rehabilitation, and modifications.

5. The SFCDC appropriation, which was restructured and replaced in the 1995 budget, includes production, operations, and support activities for the Space Transportation System which includes the Space Shuttle and expendable launch vehicles and for tracking, telemetry, command and data acquisition support of all flight projects.

6. The CoF appropriation, which was restructured and replaced in the 1995 budget, includes the construction of new facilities and the repair, rehabilitation, and modification of facilities.

7. The R&PM appropriation, which was restructured and replaced in the 1995 budget, includes salaries, travel, and related expenses for the civil servants in support of NASA programs.

In addition to the basic operating programs described above, MSFC expenditures for FY98 included $22 million of reimbursable activity.

Basis of Accounting

MSFC accounts are maintained on an accrual basis, where expenses and revenues are recorded in the accounts in the period in which they are incurred or earned. Expenses are classified in the accounts according to the appropriation that financed the activity. These expenses are coded in accordance with the Agencywide coding structure, which sets forth a uniform classification of financial activity that is used for planning, budgeting, accounting, and reporting. The expenses are further categorized in the general ledger as operating expenses or capitalized expenses. In addition, appropriated capital used does not include amounts capitalized.

Funds with the U.S. Treasury and Cash

MSFC's cash receipts and disbursements are processed by the U.S. Treasury. The funds with the U.S. Treasury include appropriated funds and deposit funds for advances received for reimbursable services.

Advances

MSFC funds its University Contracts and Grants program by recipient drawdowns on letters of credit or through the use of predetermined payment schedules where letters of credit are not used; recipients are required to schedule drawdowns to coincide with actual, immediate cash requirements, in accordance with OMB Circular A–125 and Department of Treasury regulations. Quarterly financial reporting of cash transactions is provided on Federal Cash Transactions Reports (SF 272's). Detailed monitoring and accountability records are maintained; monitoring includes audits by the Defense Contract Audit Agency (DCAA) and the NASA Office of Inspector General.

Accounts Receivable

The largest portion of accounts receivable is due from other Federal agencies and includes research and development of satellites as well as launch services. Nongovernment customers are required to provide advance payments which are placed on deposit with the U.S. Treasury until services are performed. In unusual cases, exceptions and waivers to this general rule have been granted under the Space Act, allowing customers to postpone advance payments.

Prepaid Expenses

Payments in advance of the receipt of goods and services are recorded as prepaid charges at the time of prepayment and recognized as expenses when related goods and services are received.

Operating Materials and Supplies

In accordance with with Statement of Federal Financial Accounting Standards (SFFAS) Number 3, Accounting for Inventory and Related Property, materials held by MSFC which are repetitively procured, stored, and issued on the basis of recurring demand are considered Operating Materials and Supplies.

Property, Plant and Equipment

MSFC-owned property, plant and equipment may be held by the Center or its contractors. Under the provisions of the Federal Acquisition Regulation (FAR), contractors are responsible for control over and accountability for such property in their possession.

Equipment with a unit cost of $100,000 or more and a useful life of 2 years or more, that will not be consumed in an experiment, is capitalized. Capitalized cost includes unit cost, transportation, installation, handling, and storage costs.

Real property such as buildings, other structures, and facilities is capitalized when the asset value is $100,000 or more. The capitalized value represents the total cost to NASA, including both acquisition and preparation costs. Buildings are valued at acquisition cost, including the cost of capital improvements and fixed equipment

required for functional use of the facility. Other structures include the acquisition cost of capital improvements. MSFC has use of its land under a no cost, 99-year lease with the Department of the Army.

Government-owned/contractor-held property includes land, buildings, structures, materials, plant equipment, space hardware, special tooling, and special test equipment. Contractors report each September 30 on a NASA Form 1018, Report of Government-owned/Contractor-held property. This form is certified by the contractor's representative and reviewed by a government property administrator.

Space hardware represents the largest dollar value of assets owned by MSFC. Contractor-held space hardware includes configurations of spacecraft, engines, satellites, rockets, and similar components unique to NASA space programs and held by NASA prime contractors or their subcontractors who are responsible for building, refurbishing, and launching the hardware. Contractor reporting is required for cost-type contracts exceeding $500,000 where space hardware costs exceed $75,000. These items are priced in accordance with guidance set forth in a NASA supplement to the FAR. The valuation policy allows for use of actual or estimated costs which may be abstracts of data from contractors' records, computations based upon engineering estimates, estimates from NASA contractor financial management reports, formula procedures, and latest acquisition/pricing estimates or other approved methods.

In FY96, NASA made a number of changes in its accounting policies for government-owned/contractor-held property. These new policies were also followed in FY97.

- Contractors reported only property costing $5,000 or more, having a useful life of 2 or more years and not to be consumed in an experiment. In prior years, all equipment was reported, regardless of value.

- Construction in process was reported for all property categories. In prior years, it was only reported for space hardware.

- Prime contractors were required to report on property in the possession of all subcontractors. In prior years, prime contractors were only required to extend the reporting requirement to first-tier subcontractors.

- Property values included profit or fee. In prior years, fees earned by contractors were generally not included in the valuation basis.

In FY98, NASA again made significant changes in its property, plant and equipment accounting and reporting policies and practices. These changes were made in order to implement the requirements of SFFAS Number 6, Accounting for Property Plant and Equipment, and Number 8, Supplementary Stewardship Reporting. These changes applied to NASA's government-held property as well as its contractor-held property. The major changes included recognizing depreciation, capitalizing assets in space and reporting heritage assets only as supplementary stewardship information accompanying the financial statements.

Prior to FY98, NASA did not recognize depreciation of its assets. In accordance with SFFAS Number 6, NASA's FY98 financial statements report depreciation expense, calculated on a composite basis, using the straight-line method. To determine depreciation expense, a variety of useful lives were established. Useful lives were set at 40 years for buildings, 15 years for other structures and facilities, 15 years for space hardware, 7 years for special test equipment and special tooling, and 5, 7, 10, 15, and 20 years for equipment, dependent upon its nature. In addition, a useful life of 25 years was established for the Space Shuttle orbiters. As part of its implementation of the new accounting standards, NASA increased the threshold value for property to be capitalized from $5,000 to $100,000. Property of lesser value is expensed when purchased. However, NASA continues to maintain physical accountability for property, plant and equipment at lower values.

MSFC's FY98 financial statements reflect the valuation of its property, plant, and equipment based on NASA's revised capitalization threshold and the elimination of heritage assets. However, in accordance with NASA guidance, the values do not reflect depreciation.

Other Assets

Other assets are comprised entirely of government-owned/contractor-held materials.

Liabilities Covered by Budgetary Resources

Accounts payable include amounts recorded for receipt of goods or services furnished to the Center, based on receiving reports and billings rendered. Additionally, MSFC accrues cost and recognizes liability based on information that is provided monthly by contractors on cost and performance reports [NASA Form (NF) 533, Contractor Financial Management Report]. MSFC relies on independent audits by the DCAA to ensure the reliability of reported costs and estimates. To provide further assurance, financial managers are required to test the accuracy of cost accruals generated from the NF 533's, and NASA Headquarters independently analyzes the validity of MSFC's data.

Liabilities not Covered by Budgetary Resources

Liabilities not covered by budgetary resources include unused annual leave and compensatory time and unliquidated obligations against closed appropriations.

In addition, MSFC had $269 million in contingent liabilities as of September 30, 1998. These contingencies include legal actions as well as contract termination liability. However, the probability is remote that any payments related to these contingencies will be due in the future. Accordingly, no balances have been recorded in the financial statements as contingent liabilities.

Revenues and Other Financing Sources

MSFC receives the majority of its funding through multiyear appropriations. These include 3-year appropriations for construction activities, 2-year appropriations for operational and space flight activities, and a single year appropriation for civil service payroll and travel. In addition to appropriated funds, the Center performs services for other Federal agencies and the public and receives reimbursable funding authority.

2 Fund Balances With Treasury
(In Thousands)

	Obligated	Unobligated		Total
		Available	Restricted	
Appropriated Funds	$868,595	$119,581	$5,922	$994,098
Deposit Funds for Reimbursable Advances				3,515
Suspense/Clearing Accounts				(14)
Total Fund Balance with Treasury				**$997,599**

Unobligated Restricted represents amounts from appropriations that have expired for obligational purposes.

3 Accounts Receivable, Net
(In Thousands)

	Entity Accounts Receivable	Nonentity Accounts Receivable	Net Amount Due
Intragovernmental	$7,413	$0	$7,413
Governmental	30	8	38
Total Accounts Receivable	**$7,443**	**$8**	**$7,451**

Nonentity accounts receivable represent amounts that will be deposited to miscellaneous receipts when collected and subsequently returned to the U.S. Treasury.

4 Operating Materials and Supplies

(In Thousands)

	1998	1997	Valuation Method
Stores Stock	$2,122	$2,306	Weighted Avg.
Standby Stock	315	321	Weighted Avg.
Total Operating Materials and Supplies	**$2,437**	**$2,627**	

Stores stock represents material being held in inventory which is repetitively procured, stored, and issued on the basis of recurring demand.

Standby stock represents material held for emergencies.

5 Property, Plant, and Equipment

(In Thousands)

	1998	1997	Change
Government-owned/Government-held			
Land	$0	$0	$0
Structures, Facilities, and Leasehold Improvements	320,591	334,812	(14,221)
Equipment	187,489	425,020	(237,531)
Construction in Progress	8,867	24,602	(15,735)
Total	**516,947**	**784,434**	**(267,487)**

NASA is a party to an agreement with the Department of the Army for use and occupancy of the land on which the Marshall Space Flight Center is located. The agreement is irrevocable and can be renewed on June 30, 2059, at NASA's option. There is no cost to MSFC associated with this agreement.

	1998	1997	Change
Government-owned/Contractor-held			
Land	$7,162	$7,162	$0
Structures, Facilities, and Leasehold Improvements	247,170	287,933	(40,763)
Equipment	193,646	347,484	(153,838)
Special Tooling	278,335	455,389	(177,054)
Special Test Equipment	98,826	149,469	(50,643)
Space Hardware	570,178	1,253,849	(683,671)
Construction in Progress	2,070,571	1,818,515	252,056
Total	**3,465,888**	**4,319,801**	**(853,913)**
Total Property, Plant and Equipment	**$3,982,835**	**$5,104,235**	**$(1,121,400)**

The decrease in values from 1997 to 1998 is due to NASA's implementation of new Federal accounting standards for property, plant, and equipment. Specifically, the 1998 values reflect MSFC's implementation of NASA's increase in its capitalization threshold from $5,000 to $100,000 and the elimination of heritage assets. See Note 1 for further discussion on property, plant and equipment.

6 Other Assets

(In Thousands)

	1998	1997	Change
Contractor-held Materials	$1,079,390	$1,086,267	$(6,877)
Total	**$1,079,390**	**$1,086,267**	**$(6,877)**

7 Other Liabilities
(In Thousands)

Liabilities Covered by Budgetary Resources	Current	Noncurrent	Total
Intragovernmental Liabilities:			
*Liability for Deposit and Suspense Funds	$2,328	$0	$2,328
Liability for Statistical Reimbursable Costs	0	0	0
Total	**$2,328**	**$0**	**$2,328**
Governmental Liabilities:			
Accrued Funded Payroll and Benefits	$11,175	$0	$11,175
*Liability for Deposit and Suspense Funds	1,174	0	1,174
Liability for Statistical Reimbursable Costs	26	0	26
Total	**$12,375**	**$0**	**$12,375**

*Liabilities include cash advances received from other Government agencies and public reimbursable customers. Also included are funds on deposit with the U.S. Treasury for employee's savings bonds and state tax withholdings.

Liabilities Not Covered by Budgetary Resources	Current	Noncurrent	Total
Intragovernmental Liabilities:			
Accounts Payable for Closed Appropriations	$0	$20	$20
Liability for Receipt Accounts	412	0	412
Total	**$412**	**$20**	**$432**
Governmental Liabilities:			
Accounts Payable for Closed Appropriations	$0	$618	$618
Liability for Receipt Accounts	(404)	0	(404)
Unfunded Annual Leave and Comp Time	0	20,524	20,524
Total	**$(404)**	**$21,142**	**$20,738**

8 Net Positions

(In Thousands)

	Appropriated Funds
Unexpended Appropriations	
Undelivered Orders	$238,071
Unobligated:	
Available	119,581
Unavailable	5,922
Invested Capital	5,064,661
Future Funding Requirements:	
Closed Appropriations	(638)
Annual Leave and Compensatory Time	(20,524)
Total	**$5,407,073**

9 Other Revenues and Financing Sources

(In Thousands)

	1998	1997	Change
General Fund Proprietary Receipts	$2,554	$233	$2,321
Total	**$2,554**	**$233**	**$2,321**

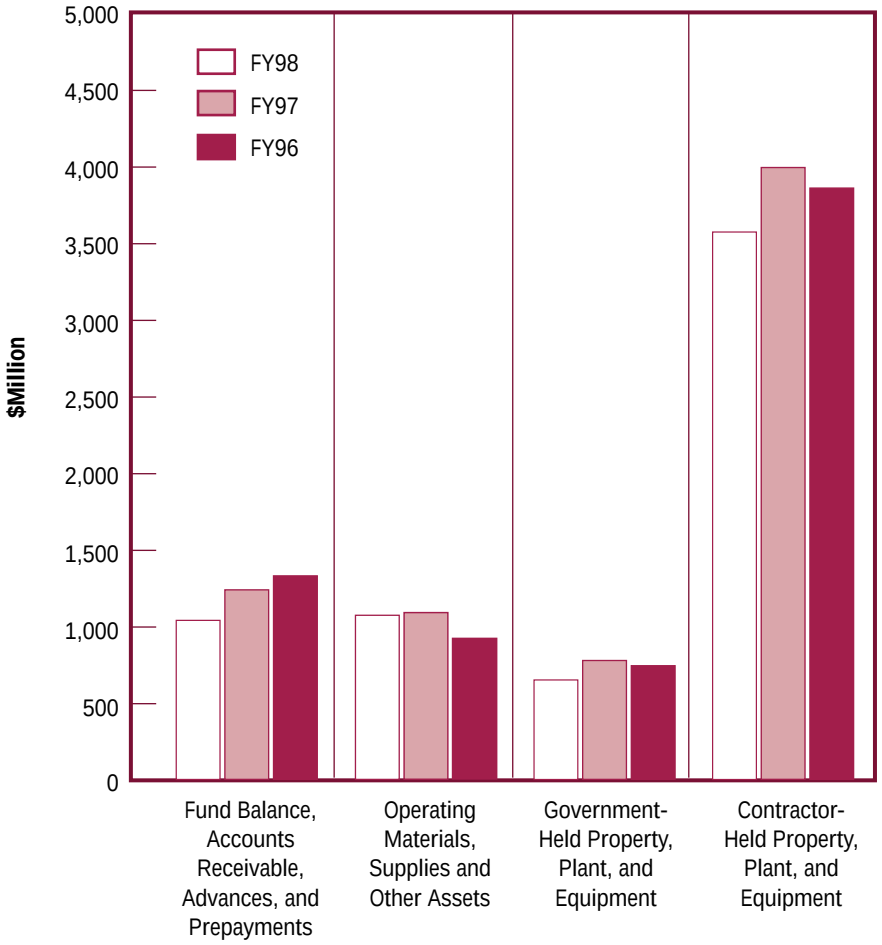
General fund proprietary receipts represent user fees, gifts, fines, interest penalties, or refunds related to closed appropriations.

Supplemental Financial Information

Assets

MSFC's assets have decreased over the last 3 years from $6.7 billion in 1996 to $6.1 billion in 1998.

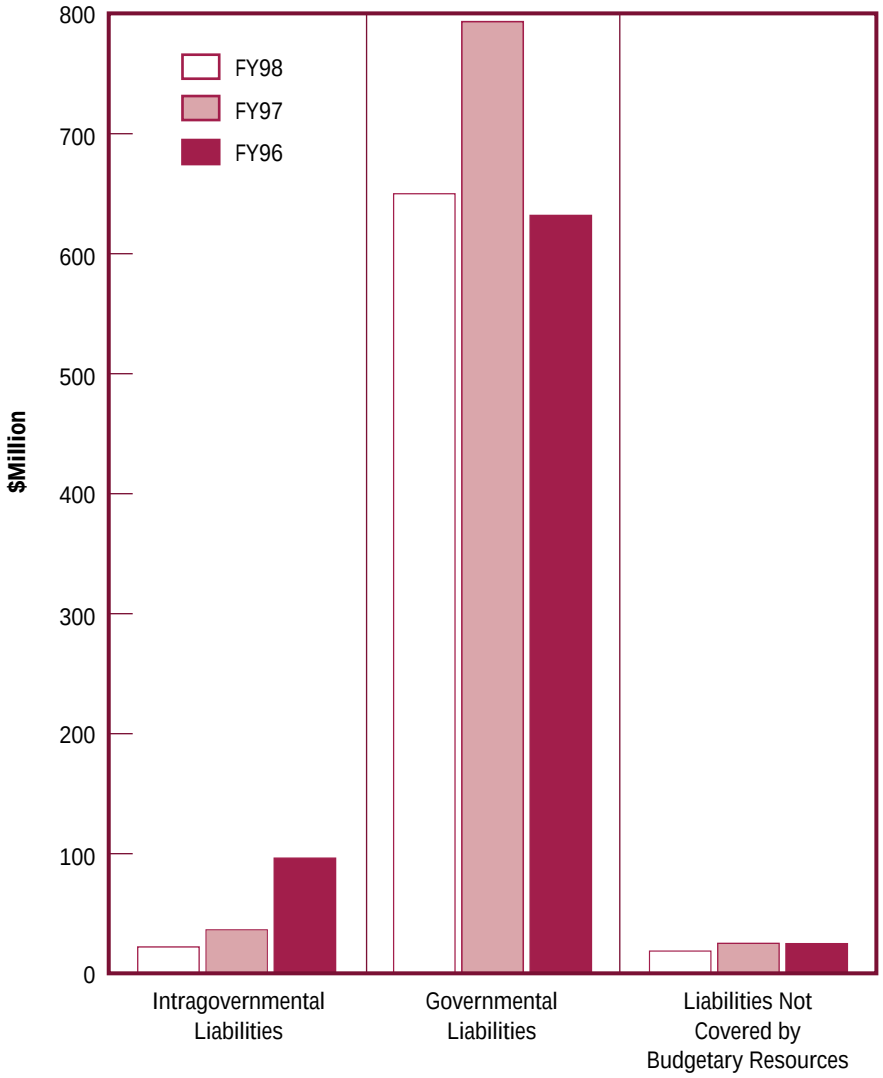
(In Thousands)	1998	1997	1996
Fund Balance, Accounts Receivable, Advances and Prepayments	$1,005,622	$1,182,818	$1,234,958
Operating Materials, Supplies, and Other Assets	1,081,827	1,088,894	910,883
Government-held Property, Plant and Equipment	516,947	784,434	774,227
Contractor-held Property, Plant and Equipment	3,465,888	4,319,801	3,817,081
Total Assets	**$6,070,284**	**$7,375,947**	**$6,737,149**



Liabilities

MSFC's liabilities have remained constant over the last 3 years at approximately $.7 billion.

(In Thousands)	1998	1997	1996
Intragovernmental Liabilities	$15,697	$22,396	$75,444
Governmental Liabilities	626,343	722,841	579,878
Liabilities Not Covered by Budgetary Resources	21,170	24,008	25,175
Total Liabilities	**$663,210**	**$769,245**	**$680,497**
% of Total Assets	**11%**	**10%**	**10%**

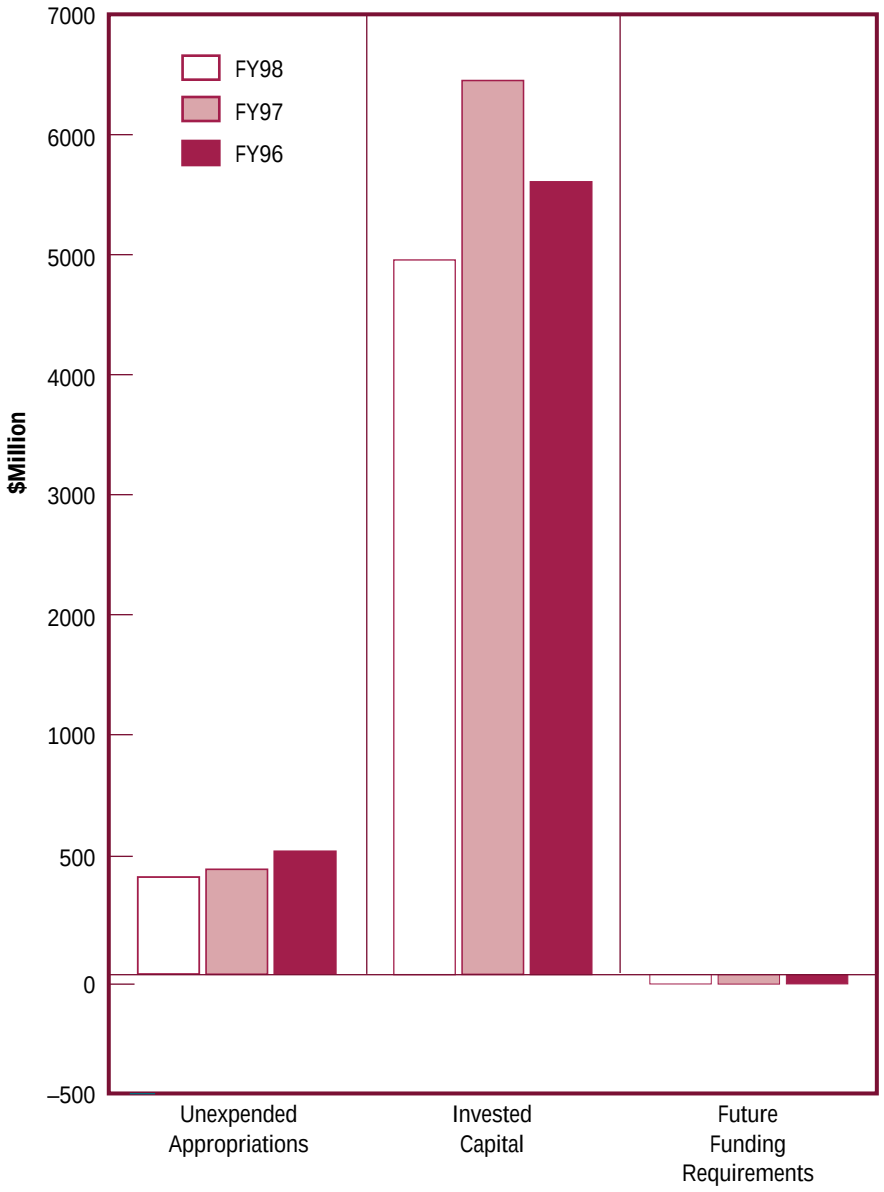


Net Position

MSFC's net position has decreased over the last 3 years from $6.0 billion in 1996 to $5.4 billion in 1998.

(In Thousands)	1998	1997	1996
Unexpended Appropriations	$363,574	$437,575	$579,620
Invested Capital	5,064,661	6,193,130	5,502,191
Cumulative Results of Operations	0	0	0
Future Funding Requirements	(21,162)	(24,002)	(25,159)
Total Net Position	$5,407,073	$6,606,703	$6,056,652
% of Total Assets	**89%**	**90%**	**90%**

% of Total Assets	**11%**	**10%**	**10%**



Unexpended Appropriations includes the following:

(In Thousands)	1998	1997	1996
Unobligated	$125,503	$95,439	$126,920
Undelivered Orders	238,071	342,136	452,700
Total Unexpended Appropriations	**$363,574**	**$437,575**	**$579,620**

Invested Capital includes the following:

(In Thousands)	1998	1997	1996
Operating Materials and Supplies	$2,437	$2,627	$2,970
Contractor-held Materials	1,079,389	1,086,267	892,312
Personal Property Held by Disposal Officer	0	0	15,601
Fixed Assets (Government-held)	508,080	759,832	753,641
Construction in Progress	2,079,438	1,843,118	1,489,664
Contractor-held Property	1,395,317	2,501,286	2,348,003
Total Invested Capital	**$5,064,661**	**$6,193,130**	**$5,502,191**

Future Funding Requirements includes the following:

(In Thousands)	1998	1997	1996
Accounts Payable for Closed Appropriations	$(638)	$(1,948)	$(1,989)
Unfunded Annual Leave and Comp Time	(20,524)	(22,054)	(23,170)
Total Future Funding Requirements	**$(21,162)**	**$(24,002)**	**$(25,159)**

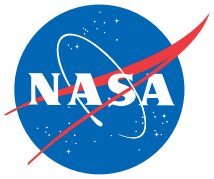
Prompt Payment Act Compliance

MSFC processed payments of over $2 billion that were subject to the Prompt Payment Act, with 99.26 percent of its 23,927 payments being on time. Interest totaling $10,168.32 was paid on 160 late payments. In addition, discounts of $167,560.33 were taken on 609 payments which were made early to take advantage of discounts offered by vendors.

Acronym List

AAR	Air Augmented Rocket
ADECA	State of Alabama Department of Economic and Community Development
AESP	Aerospace Education Services Program
AIDS	Auto Immune Deficiency Syndrome
AMCOM	Army Aviation and Missle Command
ART	Advanced Reusable Technologies
AS	Aero-Space
ASI	Italian Space Agency
ASTP	Advanced Space Transportation Program
AXAF	Advanced X-Ray Atmospherics Facility
BizTech	Business Technology Development Center, Inc.
CBM	Common Berthing Mechanism
CCAD	Central American Commision on the Environment and Development
CCI	Consolidated Contracting Initiative
CeBER	Center for Biospheric and Educational Research
CGF	Crystal Growth Furnace
CoF	Construction of Facilities
CSC	Commercial Space Center
CXM	Constellation X-Ray Mission
CXO	Chandra X-Ray Observatory
DCAA	Defense Contract Audit Agency
DTV	Digital Television
ERC	Educator Resource Center
ES	Earth Science
ET	External Tank
EVM	Earned Value Management
FAR	Federal Acquisition Regulation
FASAB	Federal Accounting Standards Advisory Board
FCC	Federal Trade Commission
FY	Fiscal Year
GAO	Government Accounting Office
GB	Gigabytes
GBX	Glovebox
GHCC	Global Hydrology and Climatic Center
GLOBE	Global Learning and Observations to Benefit the Environment
GPRA	Government Performance & Results Act
GSFC	Goddard Space Flight Center
GSRP	Graduate Student Research Program
HASP	Hands-on Alliance for Science Project
HEDS	Human Exploration and Development of Space
HIV	Human Immunodeficiency Virus
HOSC	Huntsville Operations Support Center
HRMA	High-Resolution Mirror Assembly
HSF	Human Space Flight
IFM	Integrated Financial Management
ISE	Intelligent Synthesis Environment
ISM	Integrated Science Module
ISS	*International Space Station*
IT	Information Technology
JOVE	NASA/University Joint Venture Program
LED	Light Emitting Diode

MRP	Microgravity Research Program
MS	Mission Support
MSFC	Marshall Space Flight Center
NAIS	NASA Acquisition Internet Service
NASA	National Aeronautics and Space Administration
NEWMAST	NASA Educational Workshop for Mathematics, Science, and Technology Teachers
NF	NASA Form
NGST	Next Generation Space Telescope
NIH	National Institute of Health
NMSD	NGST Mirror System Demonstrator
NSTAR	NASA Solar Electric Propulsion Technology Application Readiness
OCC	Operations Control Center
ODIN	Outsourcing Desktop Initiative in NASA
OFPP	Office of Federal Procurement Policy
OMB	Office of Management and Budget
PCA	Program Commitment Agreement
PCCA	Principle Center for Communications Architecture
PI	Principle Investigator
PMCWG	Program Management Council Working Group
POIC	Payloads Operations Integration Center
Project LASER	Learning About Science, Engineering and Research
R&D	Research and Development
R&PM	Research and Program Management
RBCC	Rocket Based Combined Cycle
RLV	Reusable Launch Vehicle
RSV	Respiratory Symcytical Virus
SAT	Science, Aeronautics and Technology
SFCDC	Space Flight Control and Data Communications
SFFAS	Statement of Federal Financial Accounting Standards
SFFP	Summer Faculty Fellowship Program
SHARP	Summer High School Apprenticeship Program
SLWT	Super Lightweight Tank
SPARCLE	Space Readiness Coherent Lidar Experiment
SPD	Space Product Development
SRB	Solid Rocket Booster
SS	Space Science
SSME	Space Shuttle Main Engine
SSP	Space Solar Power
STR	Space Transportation Research
SXI	Solar X-Ray Imager
TreK	Telescience Resource Kit
TVA	Tennessee Valley Authority
USA	United Space Alliance
USMP–4	Fourth United States Microgravity Payload
UVI	Ultraviolet Imager
VISAR	Video Image Stability and Registration
VRC	Virtual Research Center
WSF	Wake Shield Facility
XRCF	X-Ray Calibration Facility
Y2k	Year 2000



National Aeronautics and
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